THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL

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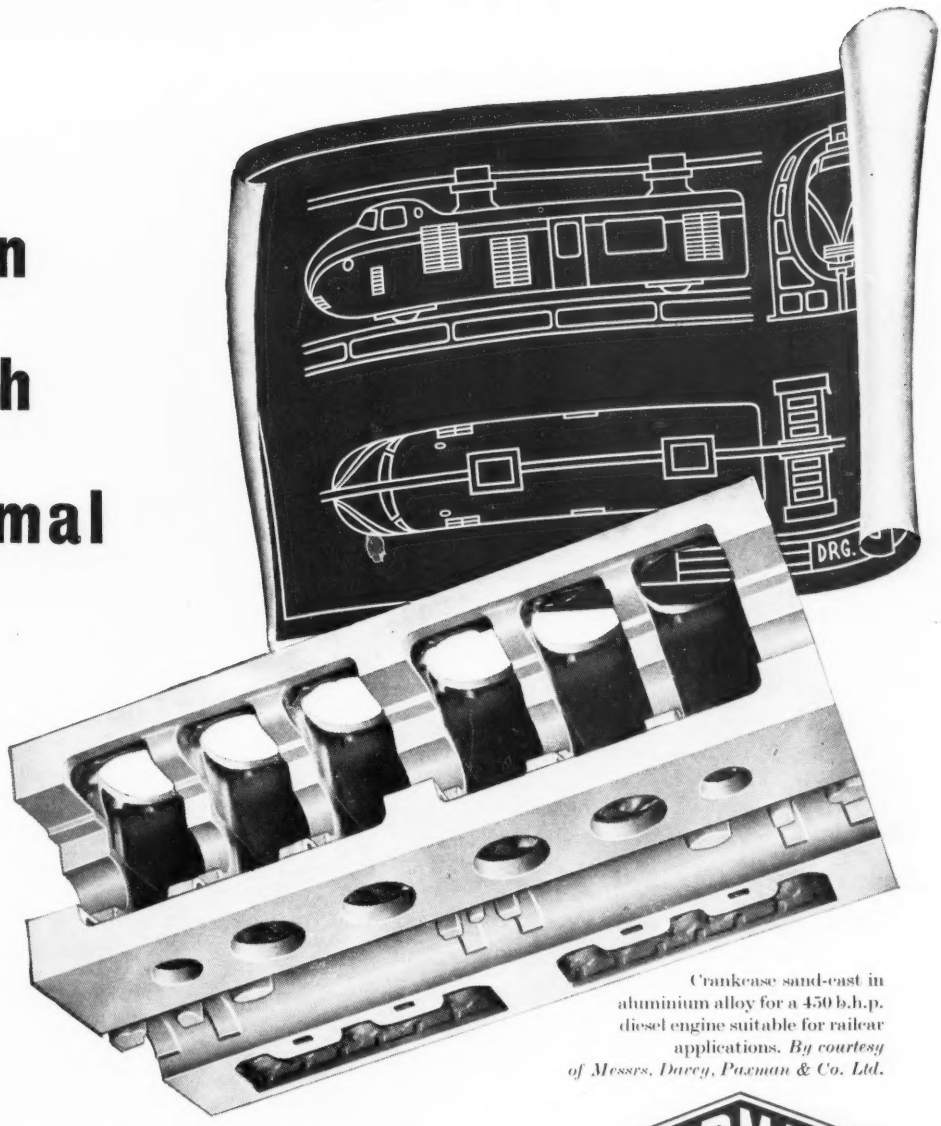

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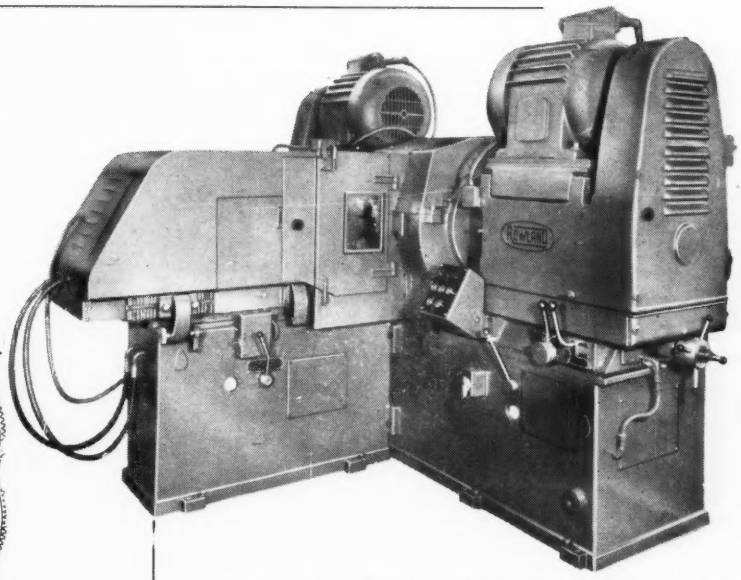

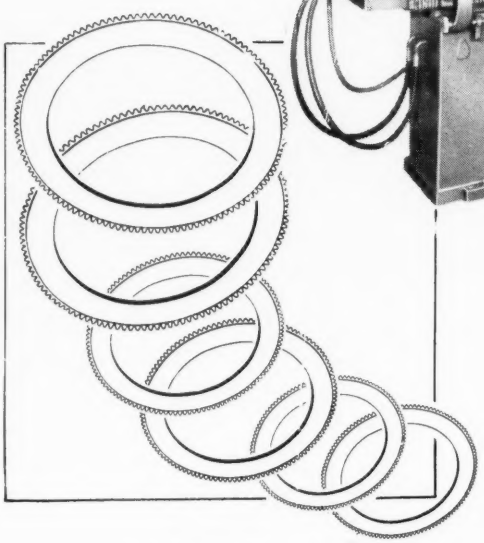

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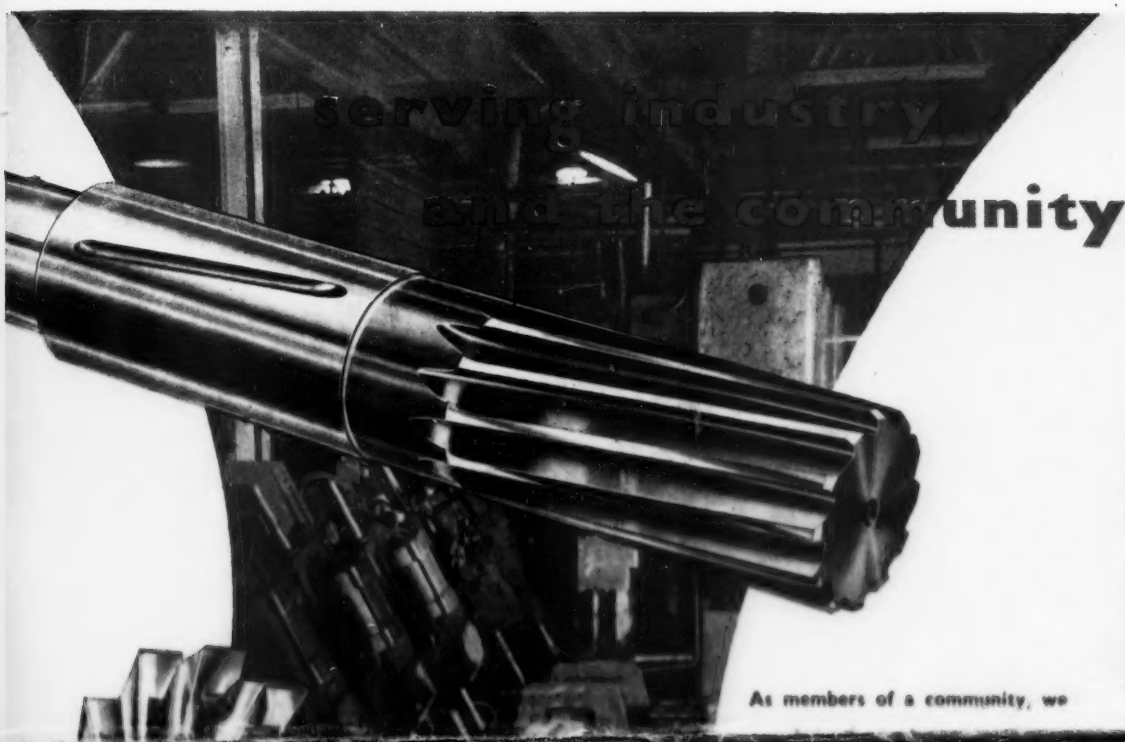
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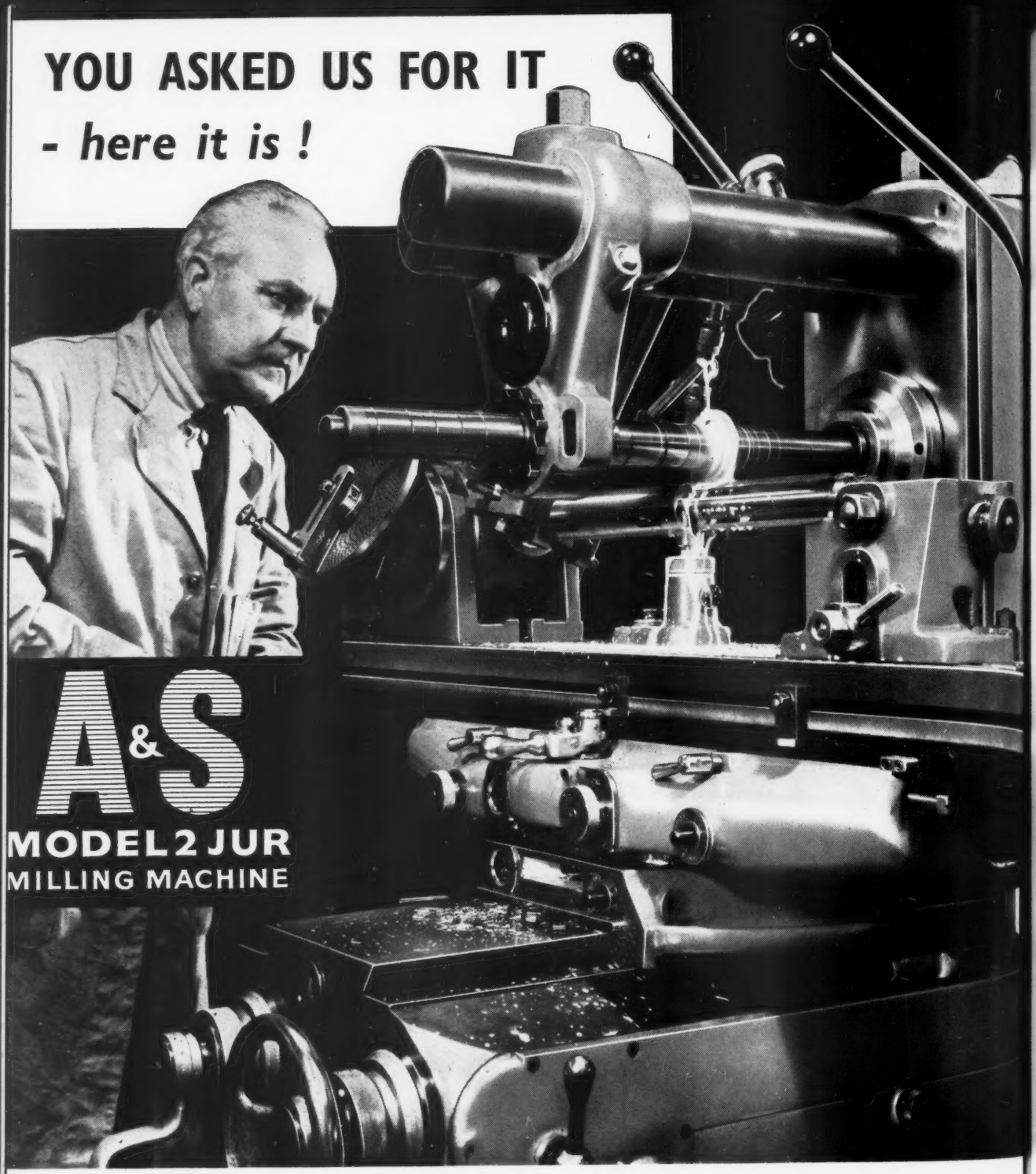

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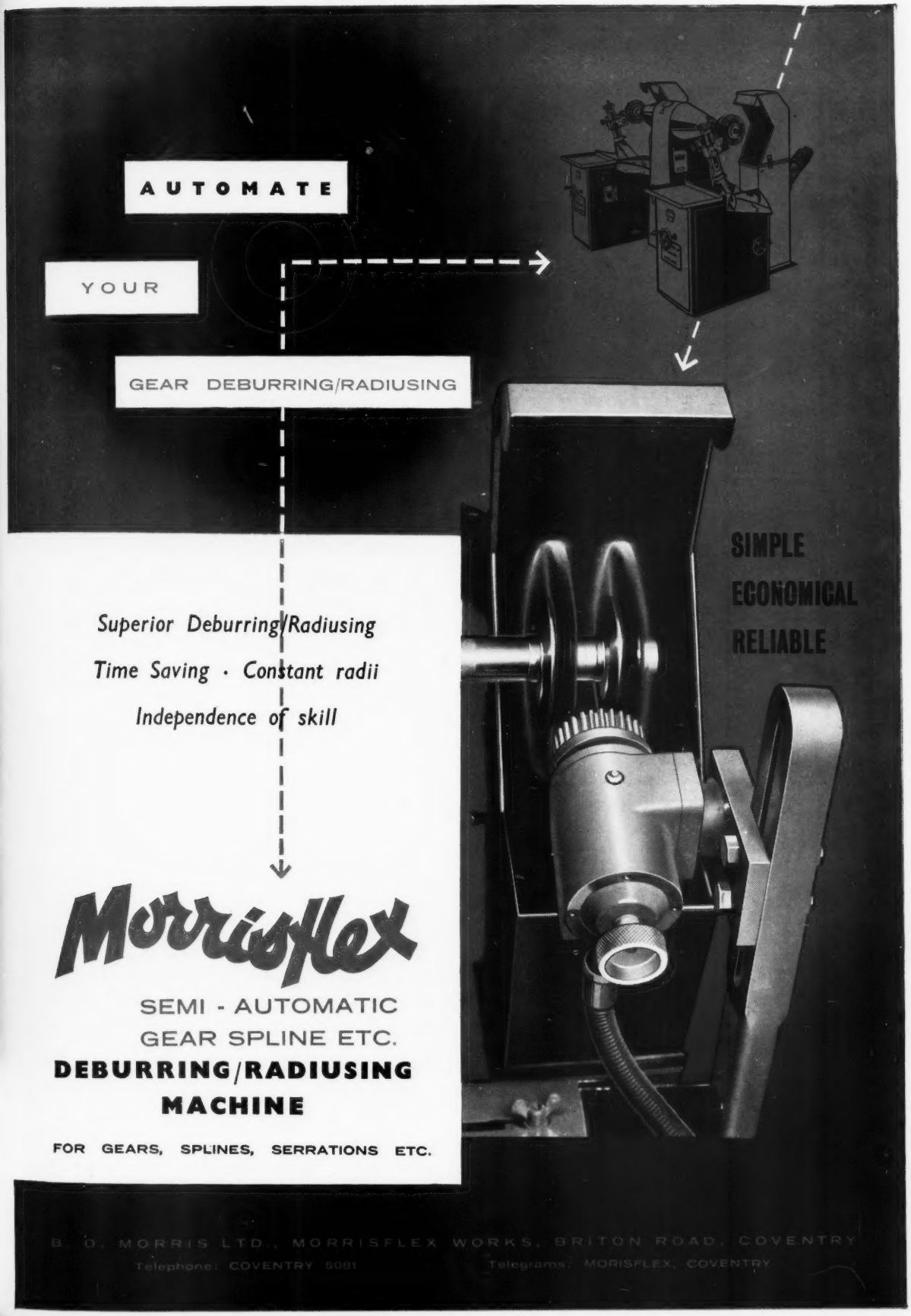

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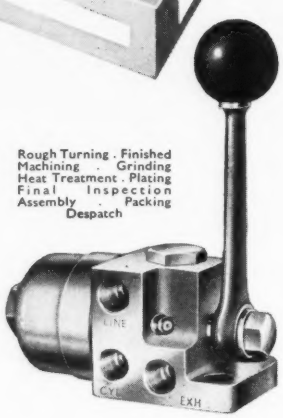

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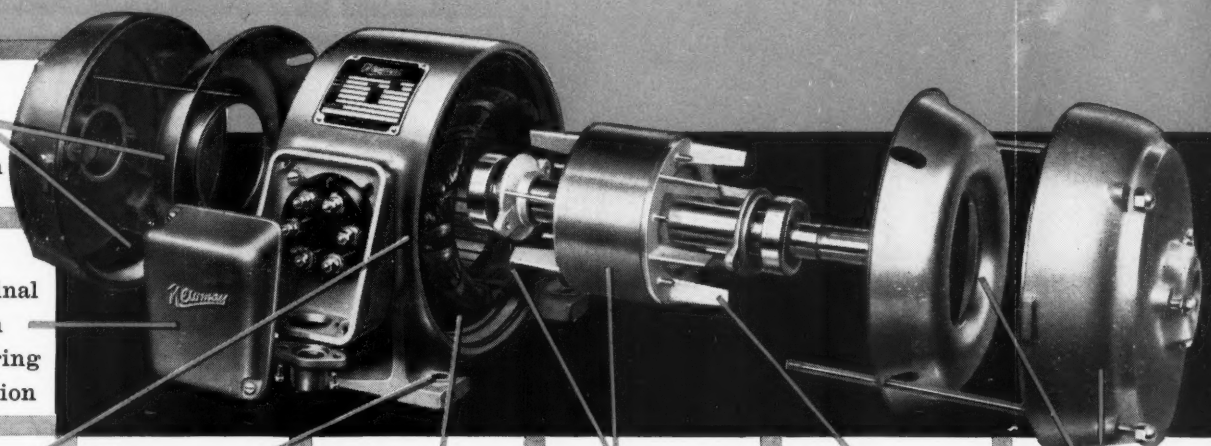

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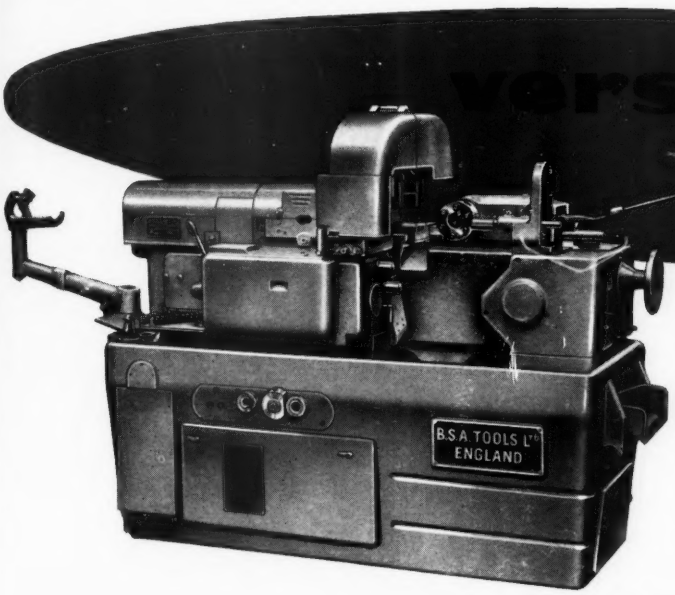


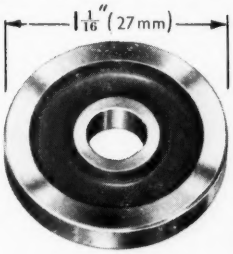
versatile

B·S·A

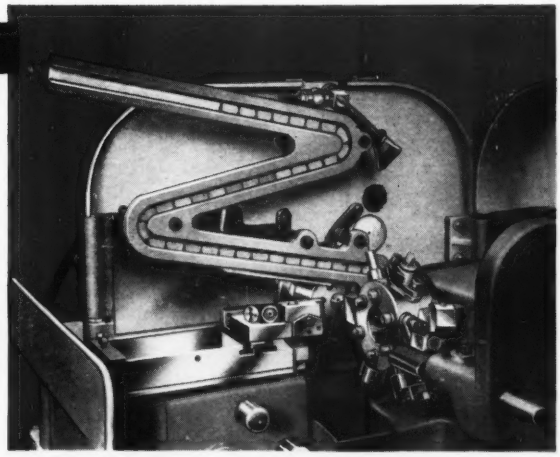
Many problems involved in the high-rate production of work of special nature or requirement are being solved by B.S.A. single spindle automatics. For work up to 2 in. diameter, from the commonplace to the most intricate, B.S.A. automatics maintain their reputation for speed with accuracy and reliability.

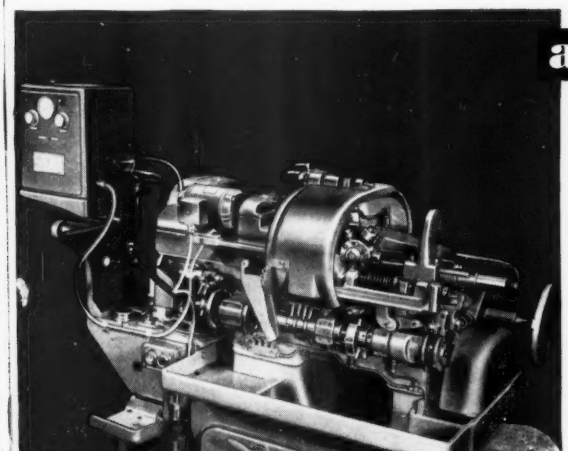
magazine loading

This bronze component is machined complete in 7 seconds on a B.S.A. 98 single spindle automatic. The "hairpin" magazine feeds the cast-blank to a loading block on the rear cross slide whence it is transferred to a chuck. Ten operations are performed involving tooling on the front cross slide, the turret and a stationary cutter within the workspindle, then the finished part is automatically released to fall in the pan.



7 Secs

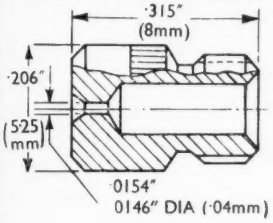




automatic inspection

Standard tooling on a B.S.A. 48 single spindle automatic produces this burner-jet in 3¼ seconds. Included in the sequence of operations is an electro-pneumatic means of automatic inspection of the fine hole. Any obstruction to an air-blast which is directed through the component causes a back pressure to be fed to a Sigma control unit. This operates a solenoid unit which stops the machine and lights an indicator. Drill replacement and removal of the defective component can then be made.

409



3¼ Secs

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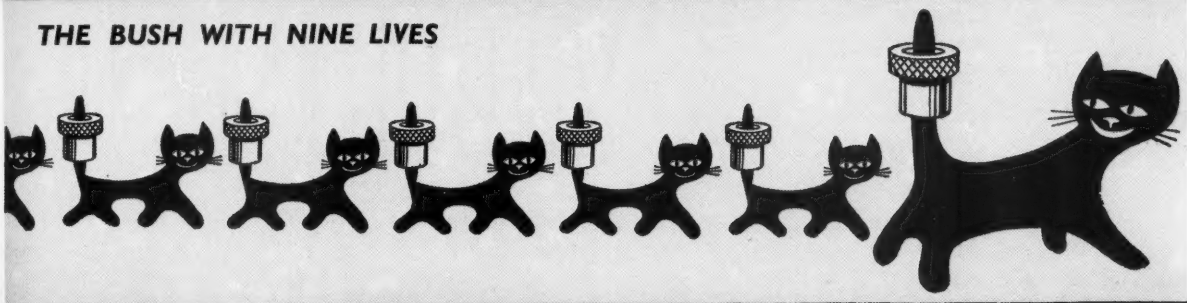

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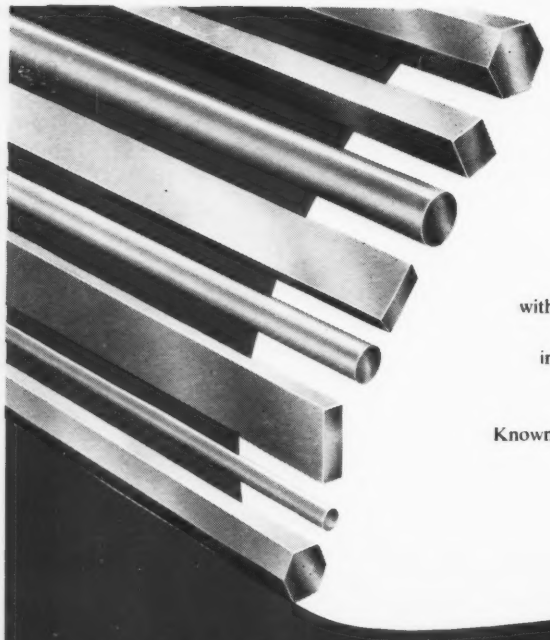

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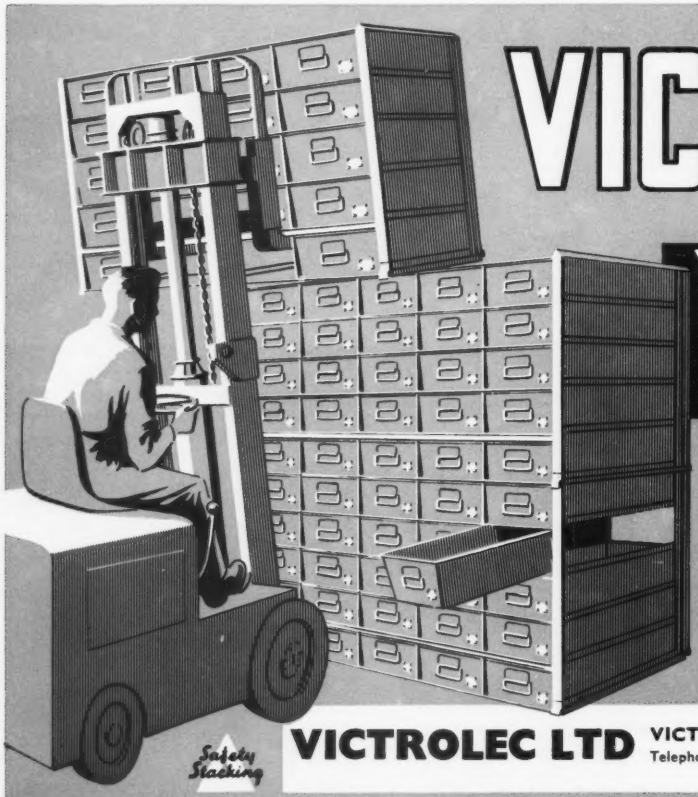

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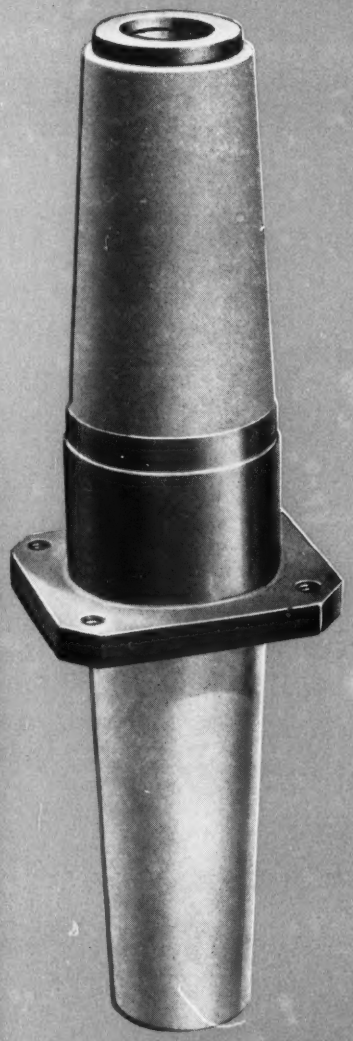
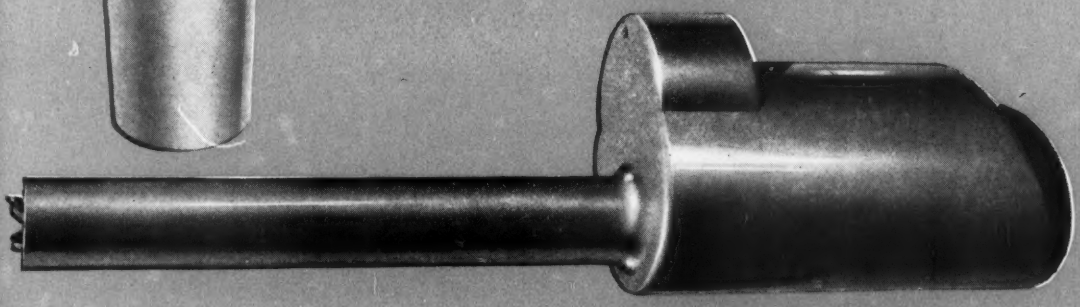


MATERIAL ADVANTAGES

Of the new plastics materials adopted by industry in recent years 'Araldite' epoxy resins are the most versatile and valuable. Their properties include remarkable adhesion to metals and ceramics, excellent electrical characteristics, high structural strength, negligible shrinkage on setting, as well as chemical resistance. The electrical industry, for example, makes extensive use of 'Araldite' resins for potting, sealing, impregnating, bonding, dip-coating and structural insulation. Gravity castings of all sizes, with or without mineral fillers, are used for insulation, insulators, bushings and structural parts. The illustrations show an insulated shroud for a 33kV switchgear earthing device and a cast 'Araldite' 11kV bushing.

A complete set of literature on 'Araldite' Epoxy Resins will be sent gladly on request.



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epoxy resins

'Araldite' is a registered trade name

'Araldite' epoxy resins are used

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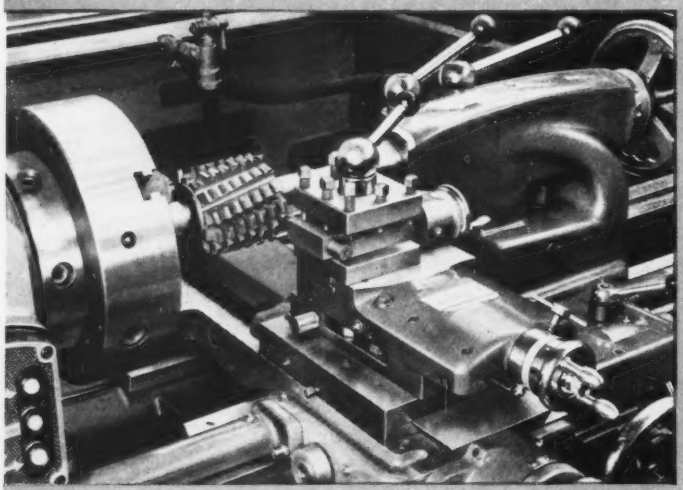

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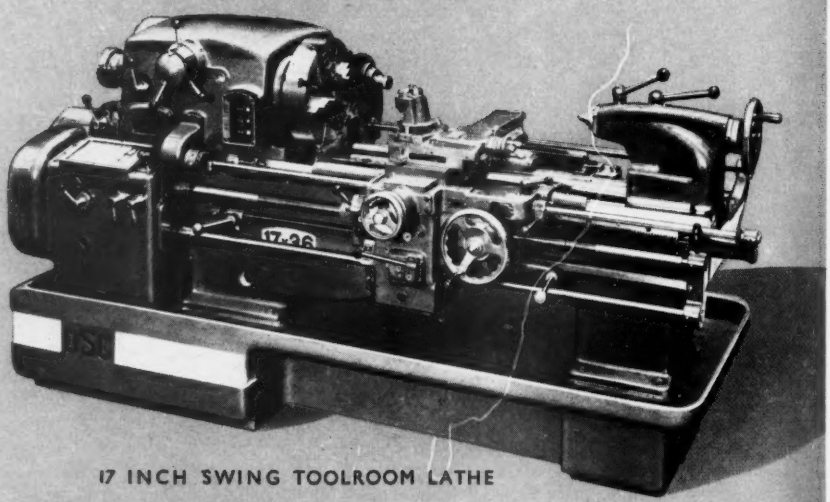

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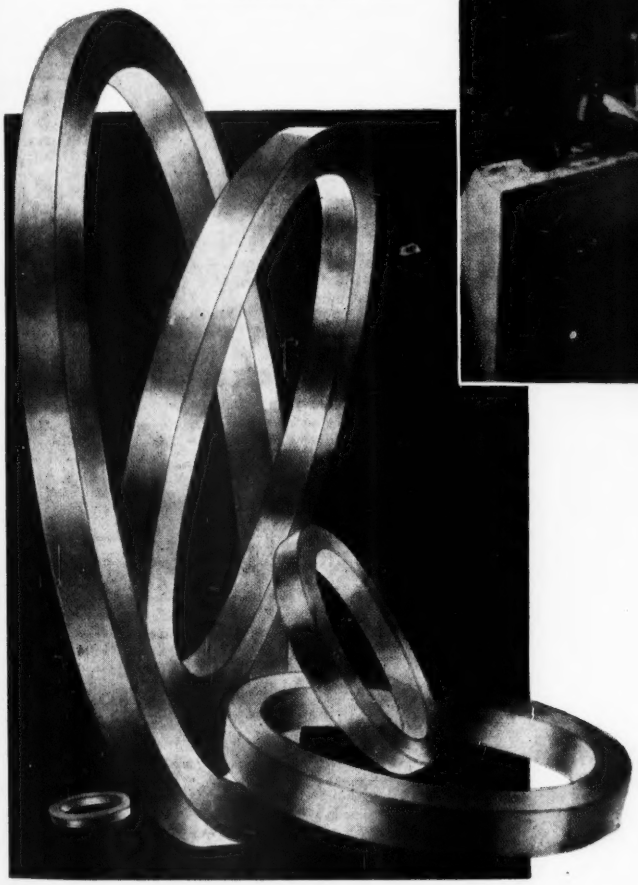
New ring-rolling equipment at the Steel, Peech and Tozer plant.



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manufacture rolled and forged rings
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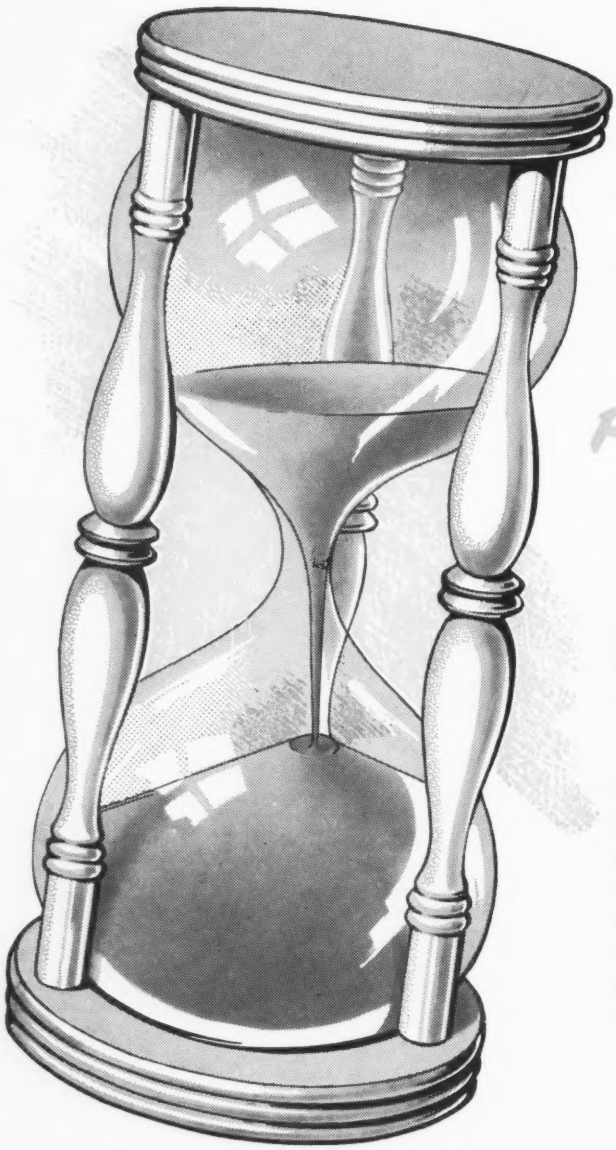
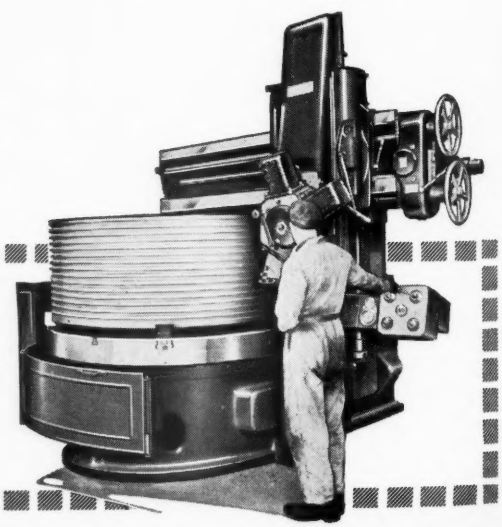


A COMPANY IS KNOWN BY THE CUSTOMERS & PROMISES IT KEEPS

Although the world-wide reputation enjoyed by the Webster and Bennett Boring Mill is based on inherent quality and fitness for purpose there are other aspects of service of equal importance.

One of those which is of particular pleasure and satisfaction to our customers, and a source of pride to ourselves, is a punctilious observance of delivery dates. No effort is spared to meet a promised delivery and although unforeseen circumstances have frequently arisen, sufficient in themselves to justify a delivery extension, deliveries quoted for machines have never been broken.

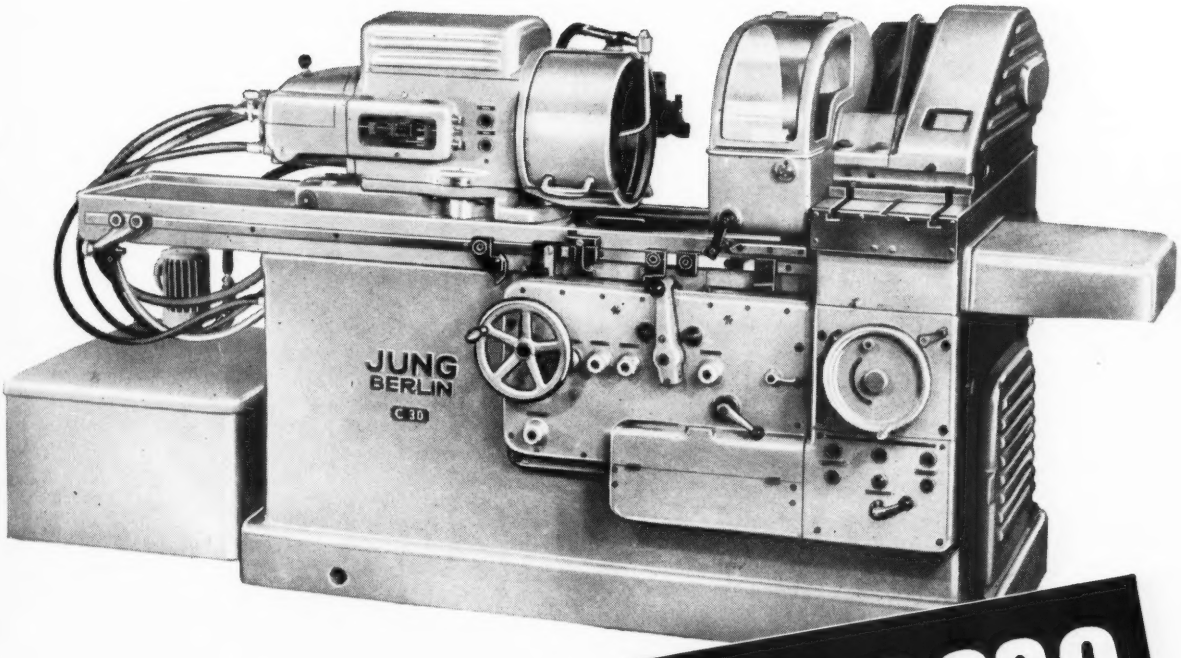


The illustration shows a Webster and Bennett 60″ Boring and Turning Mill at the Bradford Works of Crofts (Engineers) Ltd., machining a 60″ diameter vee groove pulley with a face width of 26″ having 18 grooves 1¼″ wide by 1¼″ deep.

WEBSTER & BENNETT LTD., COVENTRY, ENGLAND

The *Only* 1"–6" Diameter AUTOMATIC INTERNAL GRINDER

FOR LONG AND SHORT RUNS



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Machine can be changed from one job to another in half an hour

Extreme accuracy—high finish

Automatic sizing by diamond or plug gauge

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SPECIFICATION

Min./Max. dia. bore	1"—6"
Maximum grinding length	8"
Maximum chucking diameter in guard	13½"
Headstock swivels to one side	10°

Special chucking equipment supplied on request

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GEARED FIXED CENTRE DRILL HEAD

Made to specific requirements for light or heavy duty drilling, reaming and tapping. Each spindle rotates at correct speed for its particular duty. Vertical adjustment for each spindle as required. Designed to fit customers' drilling machines. Standardised stock components minimise cost.

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No limitations to hole pattern, however complicated. Centre distance can be as small as twice the drill diameter. Particularly suitable for drilling holes up to $\frac{1}{4}$" diameter. Designed to fit customers' drilling machines or can be used with the S.P.K. Multi-Drilling machine, making a self-contained high production unit. Unique S.P.K. system of standardised stock components minimises cost.

TELL US YOUR PROBLEMS, THEY MAY NOT BE PROBLEMS TO US!

Other time-saving products include :-

ADJUSTABLE CENTRE DRILL HEADS ..... Brochures DH101/5
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the advantages of magnesium fabrications

This portable protective barrier safeguards workmen carrying out repairs on one set of high voltage cables whilst the other set is still in operation. Fabricated for The North Western Electricity Board from magnesium alloy plate, tube and extrusions, the barrier combines exceptional lightness with strength and rigidity.

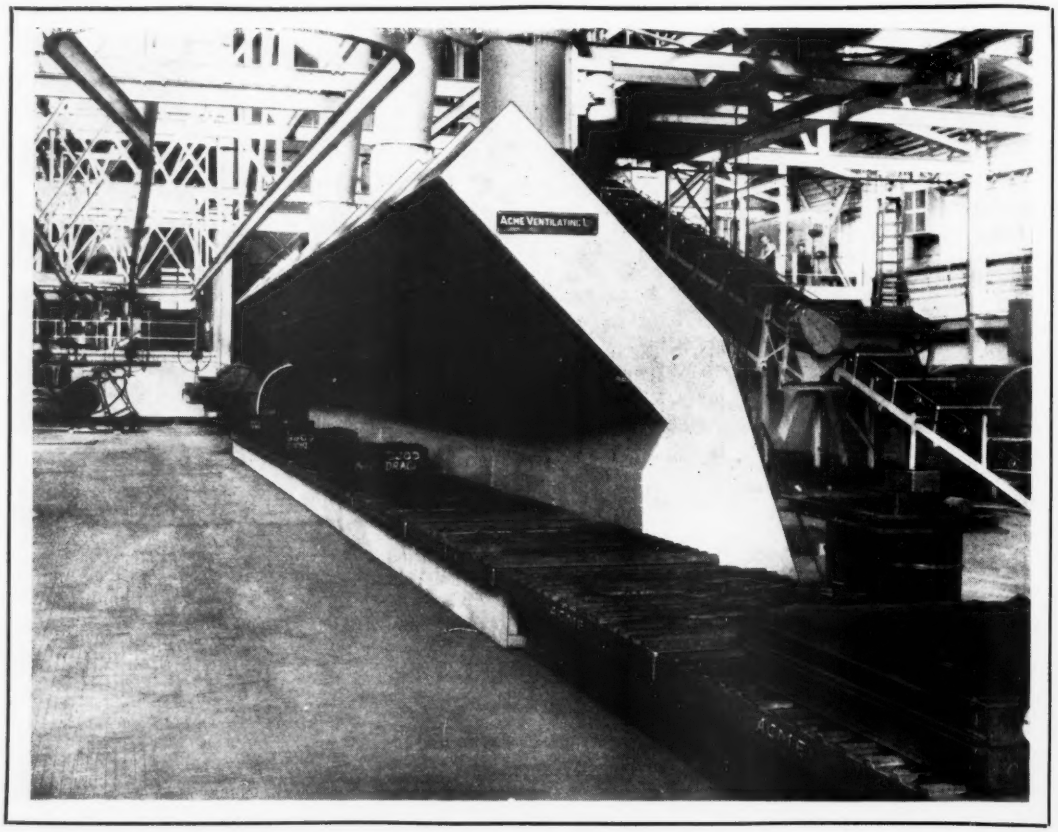
The inherent strength of the barrier was assured by magnesium's outstanding weldability. When magnesium is welded by the argonarc process stronger welds can be obtained than with most other light alloys and efficiencies of at least 75% may be expected. Wrought magnesium can also be welded to magnesium castings without appreciable loss of strength.

These and other advantages of magnesium fabrications are being brought to every industry by MEL. Their Fabrication and Assembly Shops at Clifton Junction, Manchester, are entirely devoted to magnesium; they were planned and equipped with only magnesium in mind.

Magnesium Fabrication is fully discussed in the booklet *MEL Magnesium Fabrication Facilities*. You can obtain a copy by writing to Magnesium Elektron Limited, 21 St James's Square, London SW1

kill dead weight with magnesium MEL

An Acme Installation



This is a photograph of a typical Acme Installation. From right to left it shows a Troughed Belt Conveyor from Shake-out, Magnetic Separator, Fume Extraction over Mould Conveyor and Pouring Monorail.

The 'Conveyor' range includes the Acme 'No-Leak' Apron Conveyor, Roller Conveyors, Slat Conveyors, Overhead Chain Conveyors, Belt Conveyor both Flat and Troughed, the 'Convoyer' and the 'Acmeveyor', a vibrating conveyor of modern design.

Our wide range of ventilation activities includes Dust and Fume Extraction, Plenum Heating, Pneumatic Conveying, Air Conditioning. Though the Acme Companies combine to to install complete Ventilating and Conveying installations, they also welcome individual enquiries from any industry.

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Please write for individual details or literature, or ask for a complete catalogue if required.

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Please refer to Dept. P.E.I.

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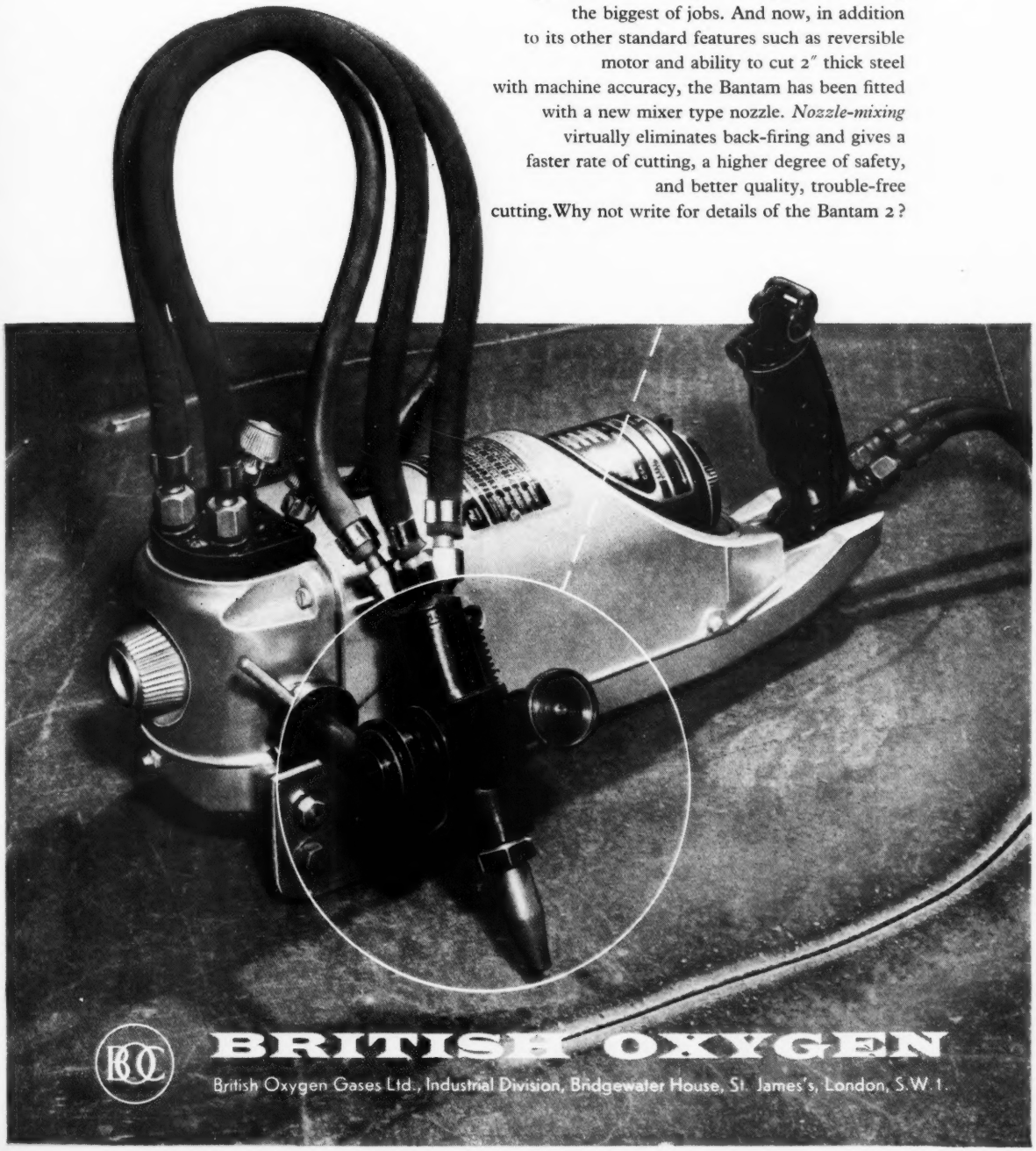
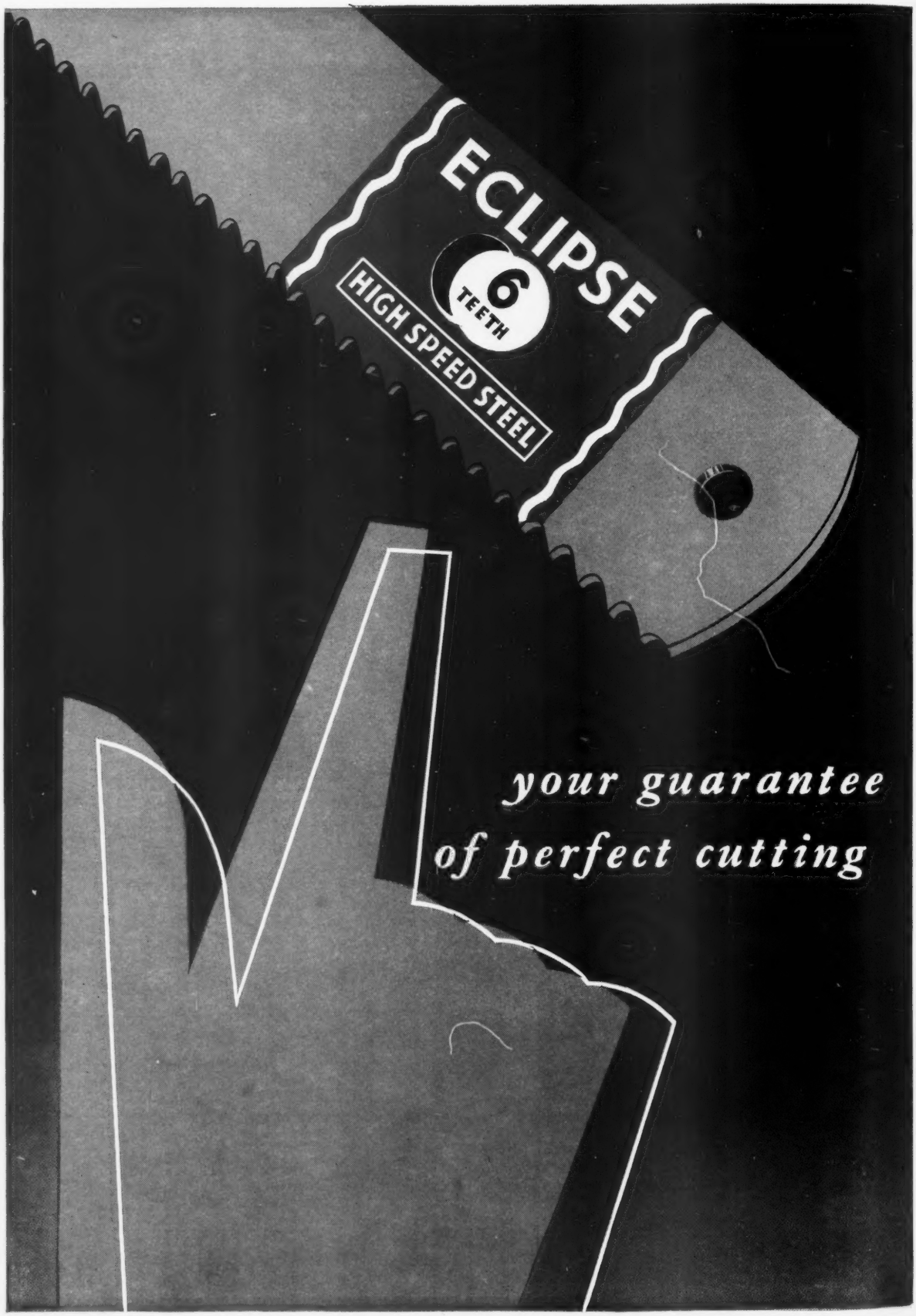
The Bantam needs no introduction: over the past two years this lightweight, portable cutter has proved capable of tackling the biggest of jobs. And now, in addition to its other standard features such as reversible motor and ability to cut 2″ thick steel with machine accuracy, the Bantam has been fitted with a new mixer type nozzle. *Nozzle-mixing* virtually eliminates back-firing and gives a faster rate of cutting, a higher degree of safety, and better quality, trouble-free cutting. Why not write for details of the Bantam 2?



BOC

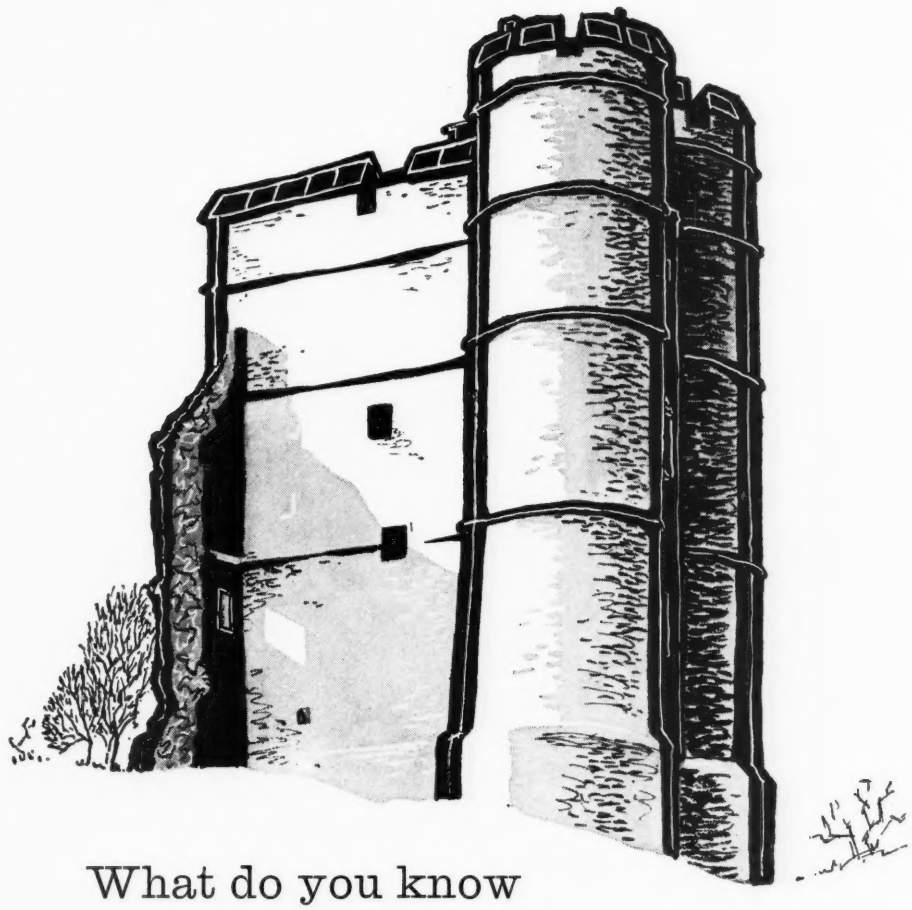
BRITISH OXYGEN

British Oxygen Gases Ltd., Industrial Division, Bridgewater House, St. James's, London, S.W.1.



'Eclipse' hacksaw blades and other tools are made by James Neill & Co. (Sheffield) Ltd and are obtainable from all tool distributors

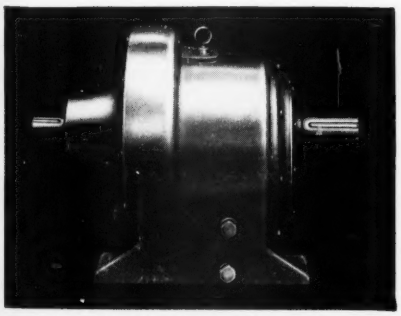
UH12



What do you know about Newbury...

Donnington Castle, situated on the outskirts of Newbury, was the scene of many sieges at the time of the Civil War, and today it still bears its cannon-ball scars in the form of brick patches, eloquent testimony of the storms of history which have swept round the town. Newbury happily combines a variegated beauty of its own with the modern amenities of a busy market and industrial town.

Oppermans of Newbury have a modern factory which typifies the industrial life of Newbury. Here, in a well-equipped plant, is manufactured a complete range of Geared Motors, Reduction Gear Units and all types of Gear Wheels. May we have your enquiries or send you descriptive literature?



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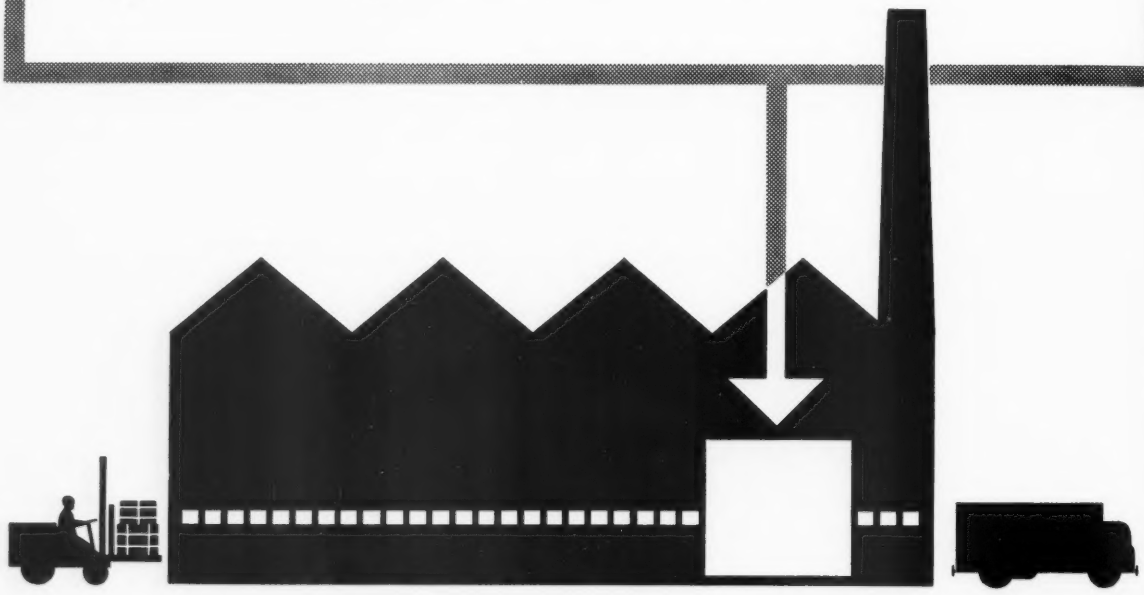
AUTOMATION OR OTHERWISE

let Wild-Barfield fit heat-treatment into your production line



More and more production engineers are finding that the installation of Wild-Barfield continuous furnaces speeds up production flow and helps to cut costs. By bringing heat-treatment right into the production line, delays and wasteful handling are eliminated. Wild-Barfield make a wide range of continuous furnaces for normalising, hardening, tempering, carbonitriding, bright annealing and other applications. All are built to the highest standards of workmanship to meet the requirements of production engineers and metallurgists. The Wild-Barfield Research Department is available to advise on your heat-treatment problems.

ELECTRIC WILD BARFIELD FURNACES

FOR ALL HEAT-TREATMENT PURPOSES

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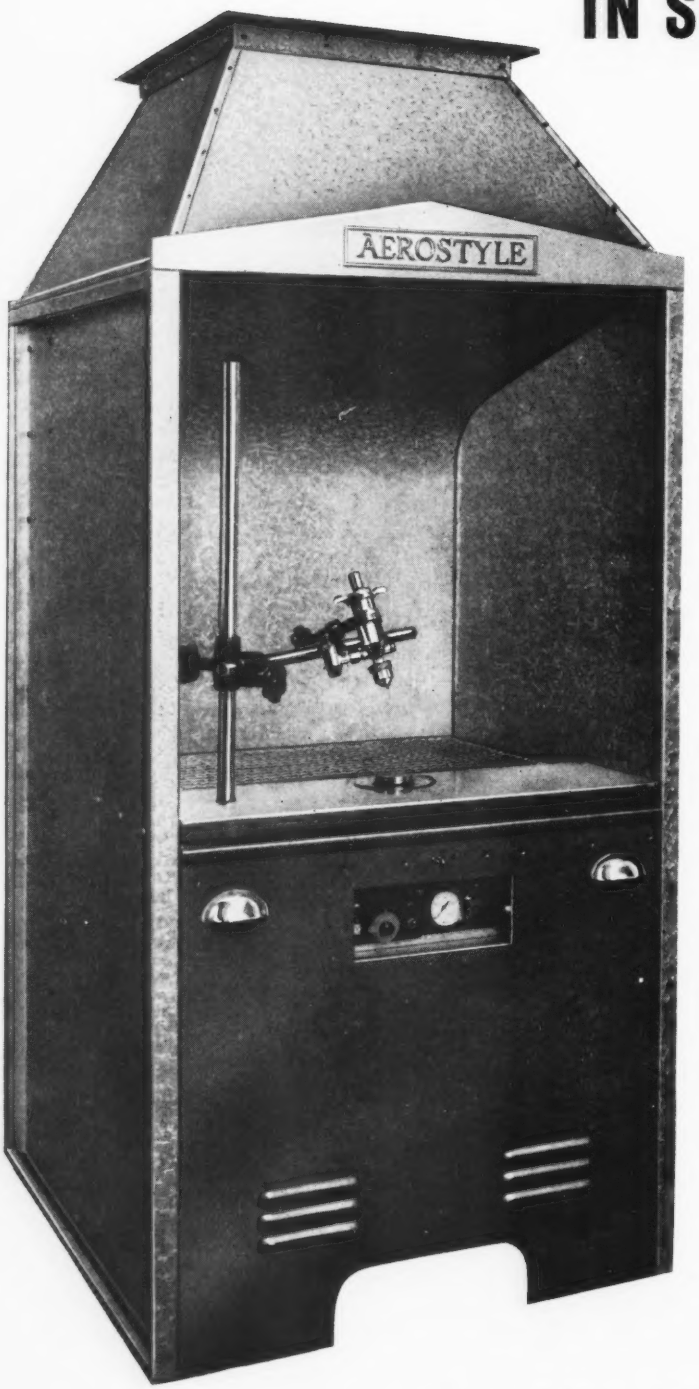
AUTOMATION

IN SPRAY FINISHING



Manufacturers wishing to paint repetition parts at high output rates with the minimum of labour and cost will find that this AEROSTYLE electronically controlled spray coating machine represents a big step forward in the automatic spraying of small components.

It is cheap to install and simple to set up. The spraying period is infinitely variable (by a simple adjustment of the electronic controller) between 0.1 seconds and 10 seconds. Once the setting has been made the operator cannot alter the amount of paint being applied, no matter how fast or slowly he works. The coating thickness can therefore be guaranteed within 1%. There is a big saving of paint as compared with manual spraying. The unit is available with from 1 to 4 spray guns, according to the type of work to be handled.

An automatic self-cleaning mask device can be supplied as an extra.

For full particulars write to :

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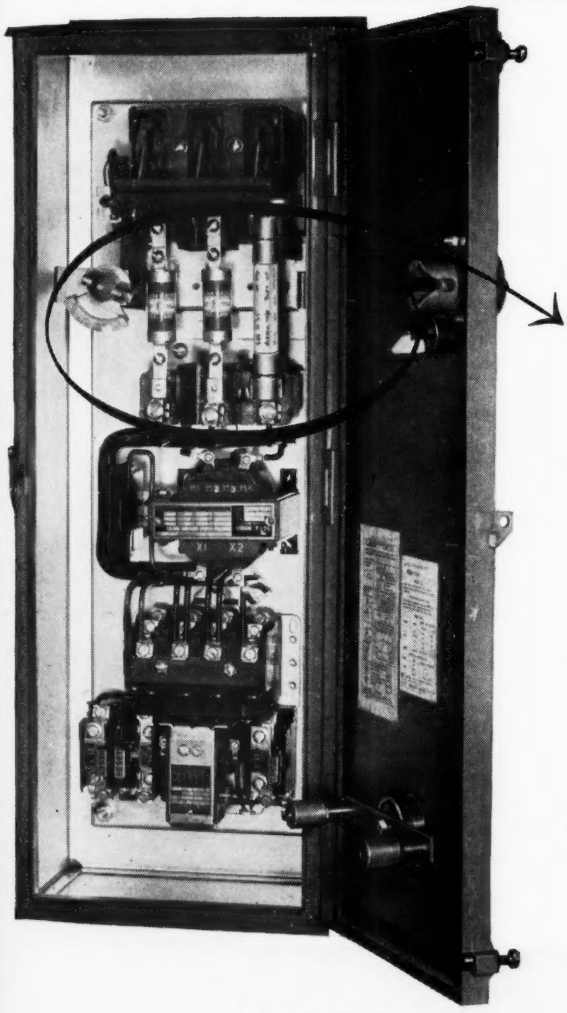

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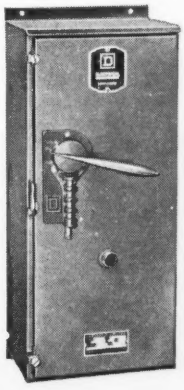

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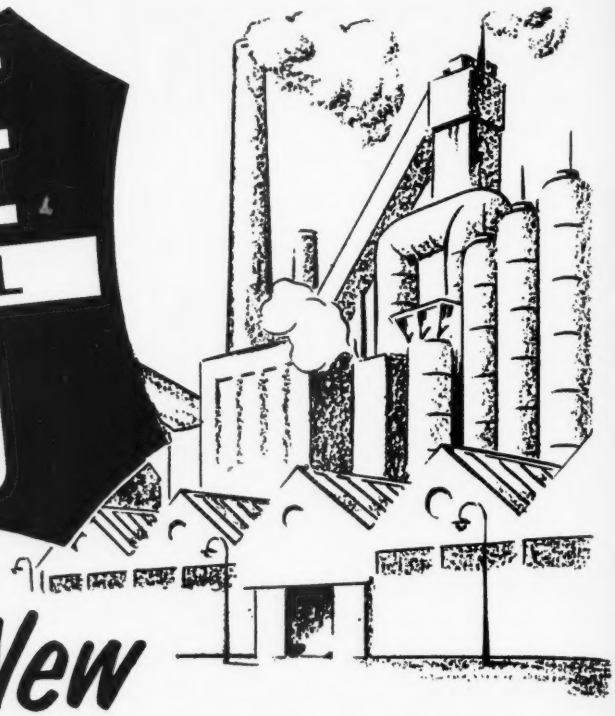

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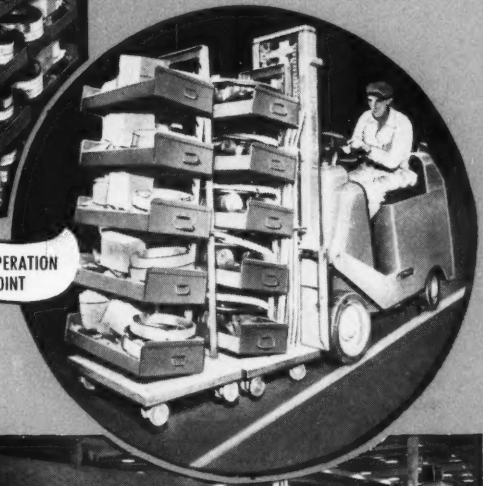

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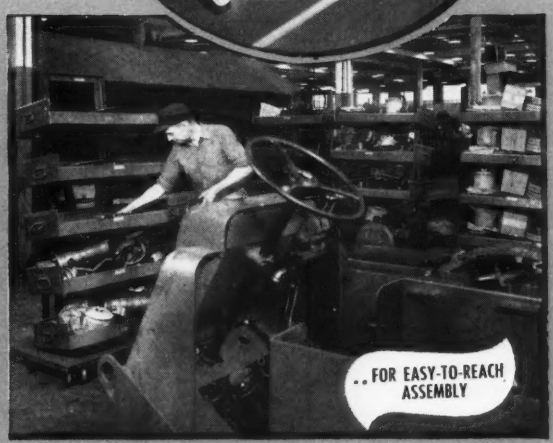

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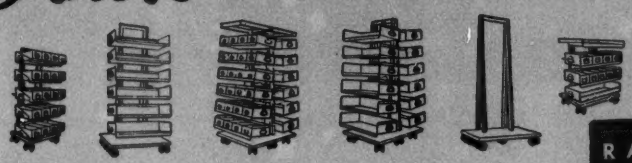

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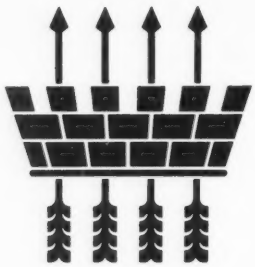

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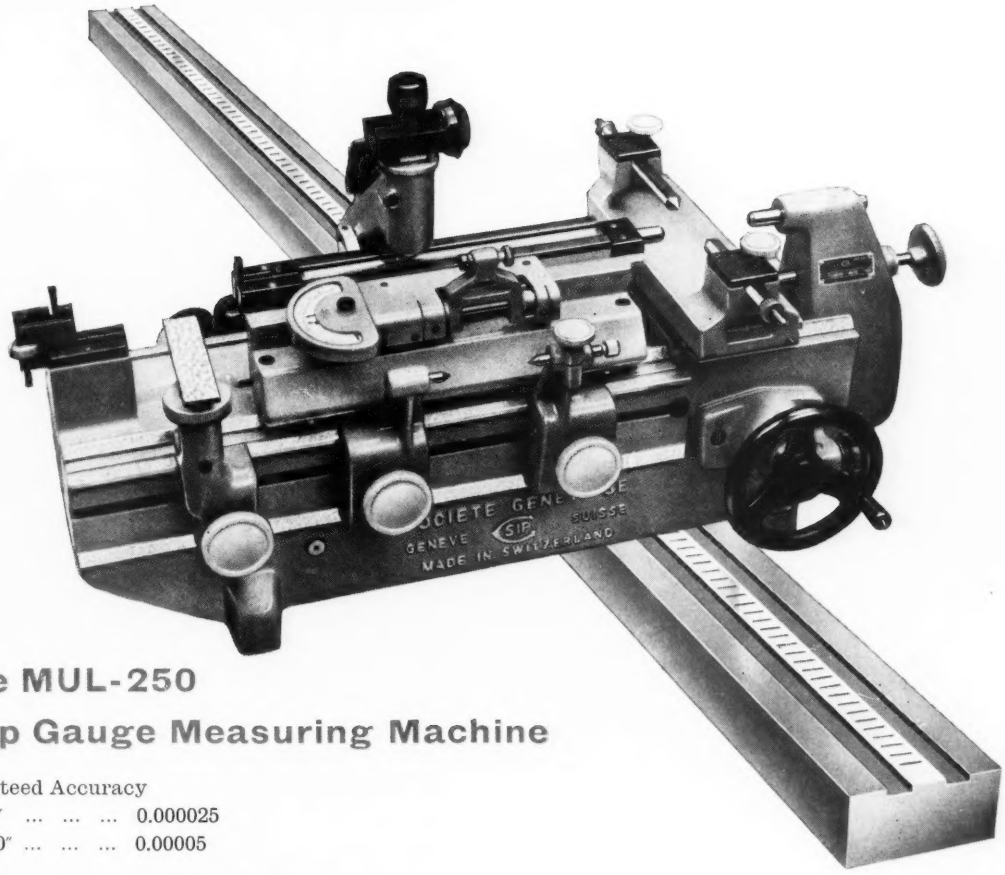

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Measuring Machines by SIP

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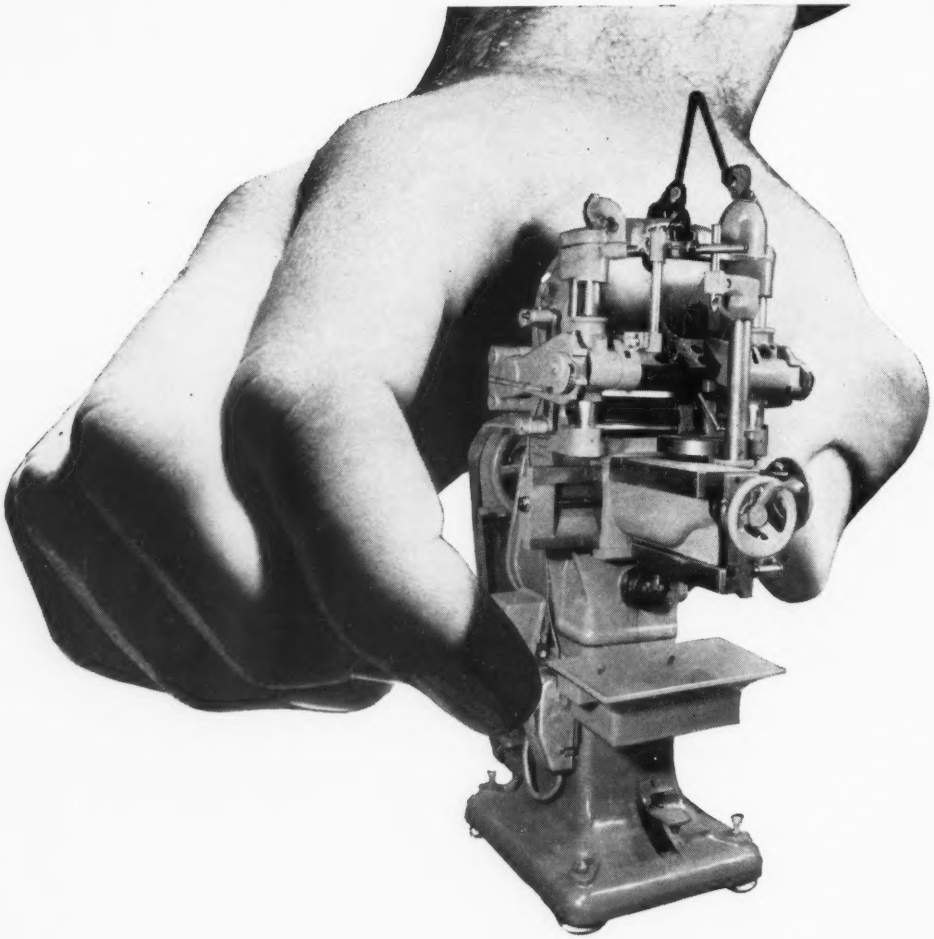

It's time you put your machine tools *in their place*

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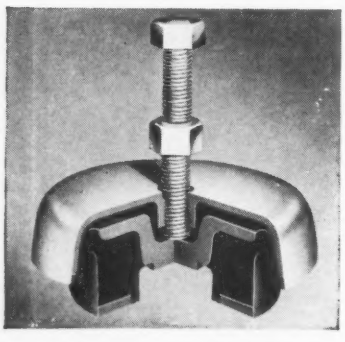

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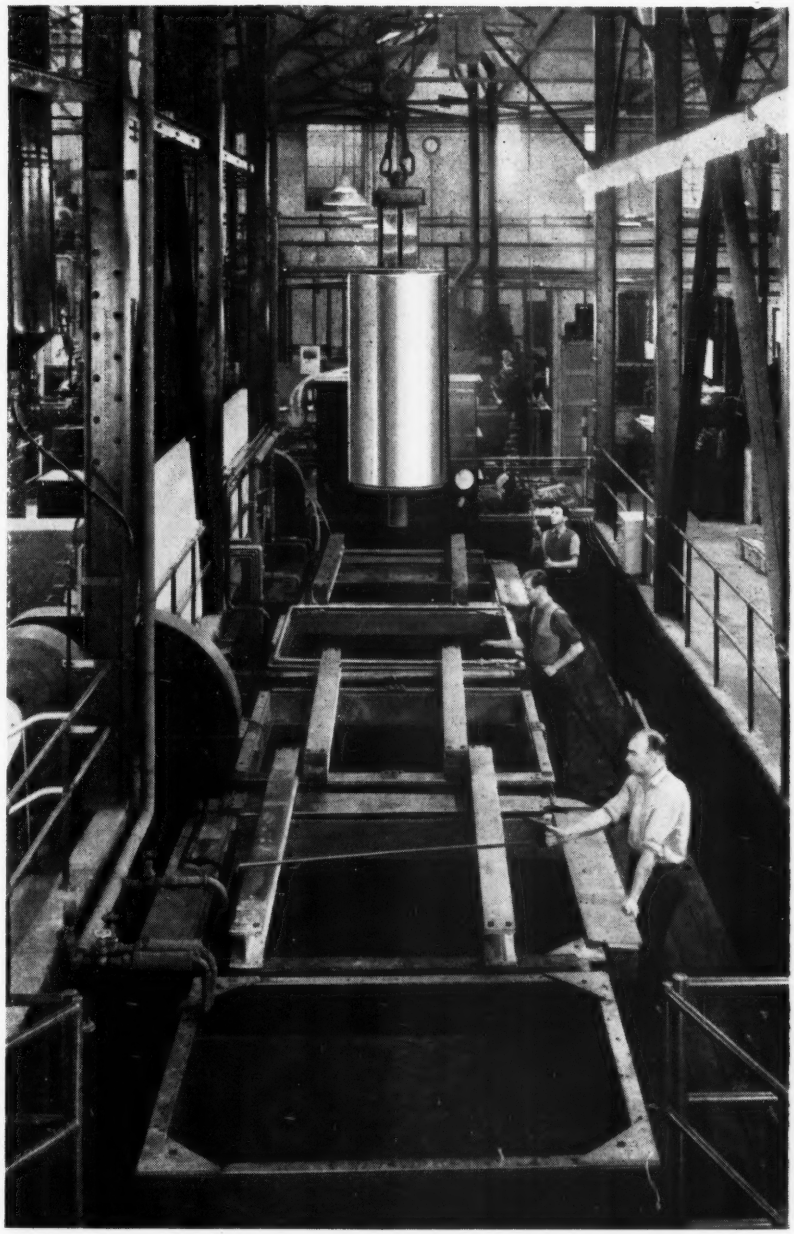

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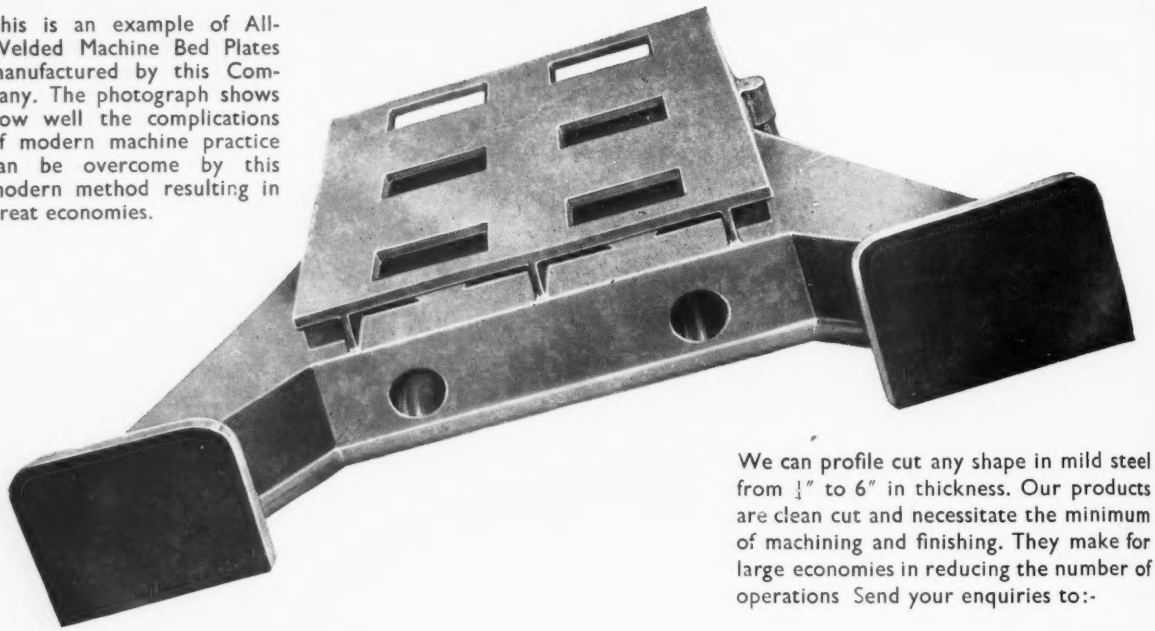

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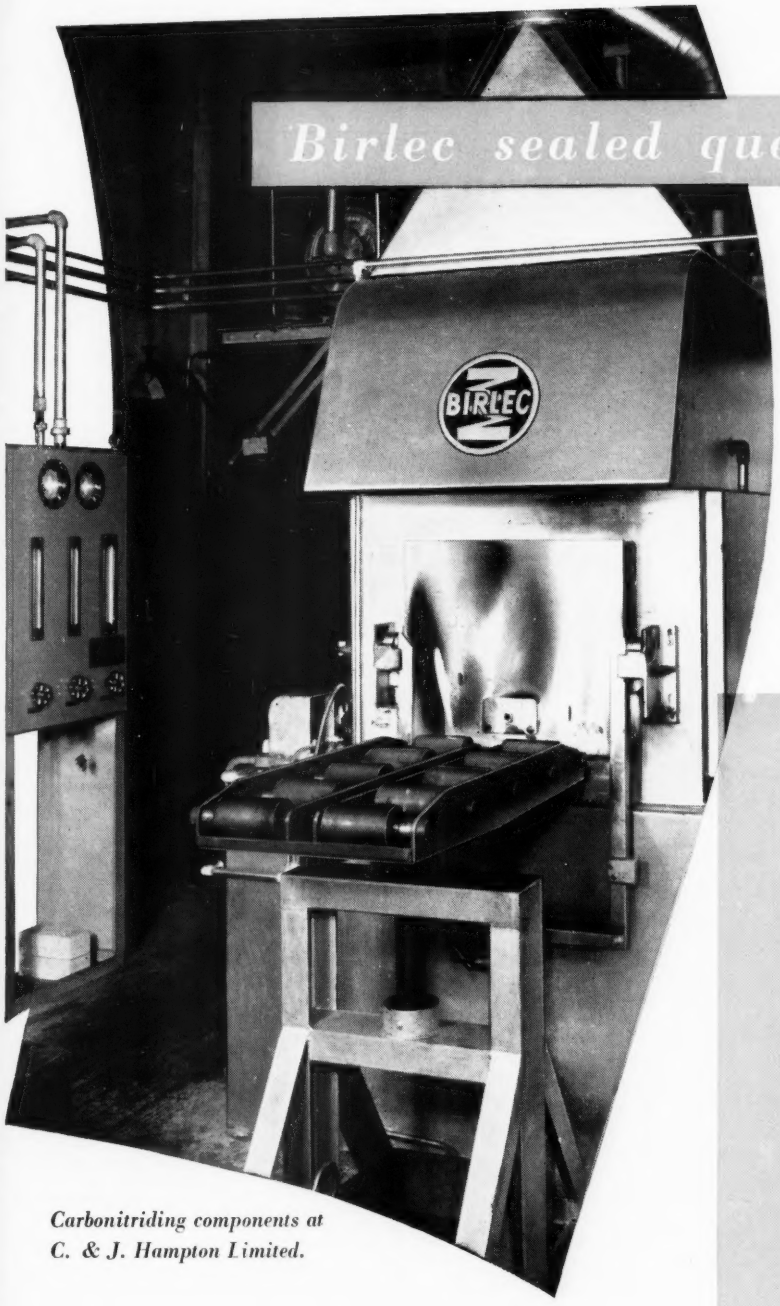

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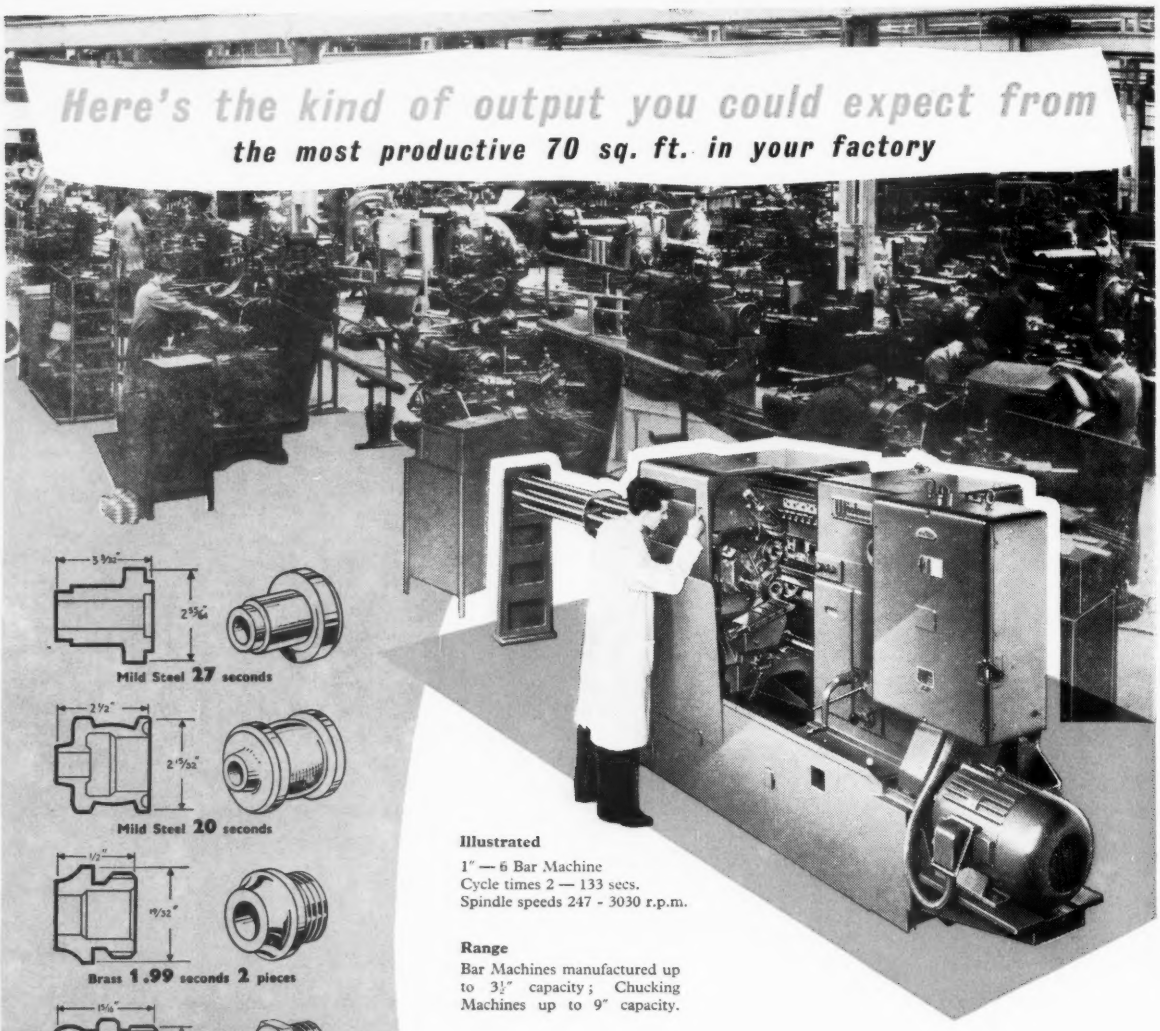
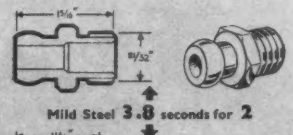


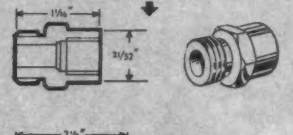
Mild Steel **27** seconds

Mild Steel **20** seconds

Brass **1.99** seconds **2** pieces



Mild Steel **3.8** seconds for **2**



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The Institution of Production Engineers Journal
VOL. 36 NO. 4 APRIL, 1957

What is Meant by Practical Training?

An Address to the Meeting of the Institution's Council on 25th October, 1956,

by Sir WALTER PUCKEY, M.I.Prod.E., F.I.I.A.,

Past-President of the Institution.

I SHOULD like to preface my brief comments on practical training by referring to the Hives Council, on which I represent the Institution. At a previous Council meeting, I gave you a very brief working report on it.

The basic reason for setting up the National Council for Technological Awards was that a tremendous sum of money, running into scores of millions of pounds, would be spent on technical education. With the tremendous growth of almost all the colleges, it was felt that we should try to get a higher concept of technical education, and a higher award which would perhaps be at the peak of all this activity, so that something bigger and better might be achieved through the practical machinery on which so much money was being spent.

It was thought that if we could devise an award which would have a national status, and be in its own way equivalent to a high university degree, but which would be operated through the technical colleges, we should in the long run bring technical college education and achievement up to the equivalent of our best universities, with the advantage that the form of education and training would be slightly different, to meet the new industrial age of the future, and that a far greater number of people would be attracted to that sphere, to reach towards higher things.

In working this out, a number of difficulties have confronted the Council. I was nominated as a representative of this Institution on the Council, and before I had been on it for more than two hours I found myself appointed as Chairman of the Board of Studies in Engineering. It is a difficult assignment and takes up a great deal of time.

Organisation of National Council for Technological Awards

Broadly, the organisation of the Council takes this form. The Chairman is Lord Hives, and below the Council are two Boards of Studies: the Board of Studies in Engineering, of which I am Chairman, which comprises a number of university professors, technical college principals, members of the Ministry and other interested parties; and the Board of Studies in Technologies other than Engineering, which has a membership of a similar nature but comprises a variety of other important studies.

One of the very important things which we set out to decide was what should be the status of the qualification and the title of the award which we would put at the peak of this great technical college activity. Finally, it resolved itself into two simple terms: the Diploma in Technology and, for engineers, the Diploma in Technology (Eng.).

The standing of the two awards themselves has been laid down as broadly corresponding to honours degree standard in universities. In order to achieve this, many technical colleges will have to increase their standards of teaching and facilities, and broaden their outlook considerably. The chances are that we shall not be satisfied with the present facilities, or with the immediately-foreseeable facilities, of quite a number of colleges.

I say this deliberately, because it is our basic intention that this award shall be something new. It must be fought for. It is not simply an alternative to a Higher National Certificate or Diploma, or even to the B.Sc.Lond. external. It is compounded of some new requirements, and when it is awarded, it must be on the basis that it represents a new high standard in the technical college field, which has never yet been reached by technical colleges generally in this country. We are not just talking of "the mixture as before", with a new label on the bottle. I am afraid that a few shocks are going to be given to the principals and staffs of some of our colleges when they hear our reactions to their applications for the approval of certain courses which are now reaching the National Council.

The Council's approval of the colleges themselves will be on an individual basis. Each college will be looked at in its own right — or wrong; frequently the latter for the moment! — and the college itself will be approved, quite apart from the individual courses. Numbers of courses are being provided in various specialities, leading to the Dip.Tech.(Eng.), in which certain variations may occur within engineering itself. When we come to the Dip.Tech. in other than engineering technologies, the courses may vary a good deal, but as a basis for approving any one course we must approve the college itself, because the background and facilities of the college are very important to bear in mind.

Turning to the practical requirements of the Dip.Tech. course, leading to the conferment of the Dip.Tech. on a student, we have laid down certain basic rules. They are reasonably flexible, but they are basic. We have not insisted that there shall be a sandwich course, popular though such courses are at present. The achievement of a Dip.Tech. award may be through the medium of full-time courses, although we prefer sandwich courses. We have laid down certain minimum times in terms of years for these courses, and it will not be possible to jump in from other courses without stringent examination of the courses. We have laid down a certain minimum standard of entry, which is much higher than the standard of entry which we normally find for the majority of college courses.

We have not laid it down that there shall be only one standard or channel of entry. We realise that there are many chaps who have done very well in industry and who may have gone as far as the H.N.C., and college principals may find it desirable to consider them for this new course. On the other hand, we realise that today, or rather tomorrow, we have to attract a far greater number of promising young fellows from our grammar schools and schools of that type to come into the field of technology. If we look at total numbers and compare ourselves with other countries, we realise that we have to tackle new sources of entry in much greater numbers to satisfy the demand for the technologists of the future. We are expecting, therefore, that the biggest entry will not necessarily come from those who have a high pass in the O.N.C., but from those who have a high G.C.E. rating and have come to a company — generally it will be based on a company — from the grammar schools or a similar type of previous education. It is in that field that we believe that our greatest hope lies, if we are to get the required numbers.

The Problem of Practical Training

One of the big problems which we face, and which we have not begun to understand properly yet, is this problem of practical training. In passing, I may mention that in setting up this new award, we envisage getting out of it a slightly different sort of man from the one who normally graduates from university. If I can put it in precise words, which is very difficult, I would say that we are trying to get a greater number of men who can develop and produce things well, as distinct from those who may be of more value in the research sphere and who may end up in a greater number of back rooms. We want to develop men who have a sound appreciation of technological principles and yet have the ability to apply those principles to a greater degree than, generally speaking, we have done so far.

We consider that, by and large, the facilities in this country for "back room" education and training are good, but the facilities for training a greater number of young men who will one day become executive managers of industry are not so good. It is towards that second sphere that we hope the greater number of Dip.Tech. men will progress.

We have therefore to consider, to a much greater extent than in the case of the universities, this blend of theory and practice, the facility to understand principles and the facility to do something more effective about them. Practical training, therefore, is an essential feature of the Dip.Tech. award and of the syllabuses leading to it.

What is practical training? We have laid down that there shall be a certain minimum time, but we are getting to the stage when we want to be even more precise about the ways

and means of assessing practical training so far as the Dip.Tech. award is concerned. The ability to devise a syllabus in which theory is taught is one thing, but the ability to equate that to the practical demonstration of that theory is something about which we have much to learn.

The practical training of an engineer is quite a different sort of thing from the practical training of a teacher or a chemist and it varies considerably with different technologies. From our point of view we are today talking about this as engineers, as people in industry, as managers in industry.

Many years ago I likened the production engineer to somebody who was present at the birth of a third dimension, somebody who sees the plan laid out in front of him and translates it into something concrete which finally is available for work, something in which the handling and fabrication of the physical components by people is an essential part of the operation; it is complementary to the theoretical exercise which either precedes it or possibly is part of it.

The Two Essential Ingredients

To the production engineer, practical training obviously means at least two essential things. It means having a personal, working contact with productive machines, and a personal, working contact with those who operate the productive machines. Here are the two ingredients of the production engineer's approach to practical training: machines and men. They are also essential ingredients to bear in mind in the Dip.Tech. courses of the future.

This so-called practical knowledge, this personal knowledge of the operation and behaviour of machines and men, is not merely an essential part of the production engineer's job; more and more people are in fact being called on to have a greater amount of that sort of knowledge. For example, the technologist, the man in the design office, who designs for production—and more and more he is supposed to design for production—must obviously have a knowledge of production in order to design for it; so that this so-called practical knowledge must be possessed today to a much greater extent than before by those concerned with design. Again, the general manager or managing director, who controls both planning and performance, must have knowledge not only of the planning function, the background function, but also of the performance function, the so-called practical side of the picture; and, as to an ever greater extent performance is linked with planning, obviously this need for practical knowledge, in the sense that you and I talk about it, is being felt not only for production engineers but for many other people, including those whose ranks the production engineer will join when he gets on in life, the senior managers.

As far as our Institution is concerned, over the years we have taken a very considerable interest in practical experience. Our Education Committee has rightly been extremely cautious and careful about it. We have insisted that this so-called practical experience is an essential part of the production engineer's outlook and requirements. I think that we are right to assume that practical knowledge is an essential ingredient of our job. We have achieved, I think for the better, the status which we have today, where we are regarded as an Institution which has great practical knowledge, but which at the same time is increasingly looking towards the principles which will enable us to operate our practice more effectively.

I wonder whether this Institution has resolved, in the light of the new circumstances, the problem of what is the right amount of practical knowledge, what indeed is the right practical knowledge ? Many things are changing rapidly today and are forcing us to look at our so-called practical content very critically indeed. For example, practice itself is becoming very much more specialised. The ability to operate certain machines and to go through a regular apprenticeship was much more simple yesterday than it is today, or than it will be tomorrow. If we think of all the technologies in which we are interested today, and even which are represented in this Council Chamber, we realise that practice in itself is a very considerable thing. It is so wide that we have to specialise to a much greater extent than ever before. Have we laid down the right sort of practice to prepare our young men for the very wide spheres of technology which exist today?

Increasing Demands on Education

Again, the educational years themselves are increasing, and the demands on education are increasing. If we look at the syllabuses of many of our colleges, we find increasingly that they are called on to bring in things which were not realised a few years ago, to such an extent that

it is much more difficult than before to allow enough time for what we consider the essential basic practices to be injected into the regular education of our young men. We should like to feel that they are able to get to work before they are 50, but at the present time the tendency is for so many other things to be put in that some things simply have to be squeezed out. Various subjects are coming in which make a bigger and bigger demand on time and which could extend logically almost to any length, certainly well beyond the formal educational period.

Then again, theory is becoming more difficult. I am not talking only about the more general subjects, such as industrial administration and a whole variety of liberal subjects, including report writing and English, but the technical theory. For example, in electrical engineering entirely new subjects are coming in, such as mathematical and control problems, and in the field of nuclear energy an entirely new set of possibilities arise. Whatever technology you take — electrical, chemical or any other — the theory is becoming more and more difficult to understand and the basic principles are taking longer to put over.

The effect of this is, in the first place to make our training problems more complex and, secondly, for them to take up more time. There may be a tendency for the so-called practical training to be cut down, for much more theory to be taught, of necessity, and for practice, if an overall time limit is imposed, to be squeezed out on the assumption that it is going to be done at some later date ; in fact it may not be done at all. We face the dilemma that we want more and more people who are able to understand the practical side, but find that so many more things are being imposed on us that the practical experience is likely to be squeezed out and be taken at some later date, or perhaps never.

This difficulty confronts the National Council for Technological Awards. We have, as I told you, created this award to encourage the more effective education and training of a greater number of men who can translate theory more effectively into practice, having some knowledge of both theory and practice. One possible solution may be the sandwich course, if this will give us the right sort of combination.

What is a Sandwich Course ?

Sandwich courses, as you know, are not new. The evidence shows that all over the country greater numbers of sandwich courses are now being planned. What is a sandwich course ? Which is the meat and which is the bread ? How long should it be ? There are various problems arising which it would be interesting to discuss with you, and on which I shall be glad to have your views ; we have laid it down that, by and large, in a sandwich course the time spent on the practical training side should be roughly equivalent to the time spent on the theoretical side. To quote an example, one college has a five-year course, in which two-and-a-half years (in six monthly periods) approximately, are spent in the works — one works or another — on some aspect of practical training, the other two-and-a-half years being spent in the college on a variety of aspects of theoretical training or the development of principles.

A number of questions emerge from such a sandwich course which I think have a general application. The Delft Report, which you considered this morning, raises a number of these questions, but it has been pointed out that it deals with university students, and should not be equated too closely with the Dip.Tech award or with practical training in the context in which I have been considering it here. On the Continent, what may be called the practical disposition of the training, is in my view, generally nearer the Dip.Tech. than the practice of the universities in this country, so that the universities here are in a slightly different category and are set up in a different way from those that I know on the Continent. If we may assume that many of the comments in the Delft Report are valuable in relation to the problem which we are considering, we will leave the Delft Report on one side for the moment.

My questions to you are these :-

1. Do we consider that a sandwich course is the most effective course to train a greater number of the sort of people that we have in mind ? That is, those who know the theory and the principles and who have the ability to translate them effectively into practice ?
2. Do we consider that the 50/50 basis which most colleges seem to regard as desirable and are planning to achieve is, in fact, the desirable split as between the theory and the practice ?
3. Do we consider that the minimum period of four years which we have laid down is, in fact, a desirable period ? Is something less than that regarded as possible, or would you

agree with some people that preferably we should consider the minimum time in which the Dip.Tech. can be achieved is five years ? I refer to five years on a sandwich course basis.

4. Should the students be based upon industry before they go in for the course, or on the college ? I want to explain that more fully. In most cases it is felt that it would be desirable for young men who have achieved a certain standard in the G.C.E. and come from, say, grammar schools to be taken on by a company. In such instances, they are regarded as members of that company, and the company may regard it as essential that they should be released for a full-time, four-year, or five-year sandwich course leading to the Dip.Tech. In other words, the company assumes the basic responsibility for engaging them and paying them an appropriate amount, which can vary, during the whole of that time, and will receive them back in a sandwich course for appropriate practical periods. Is that considered to be desirable, and is industry generally prepared to take on a greater number of these young men and thereafter to release them and pay for them for this length of time, leading up to this award ?

5. This is one of the most important questions of all. If it is accepted as desirable to have industry-based students who would be released for this course, would it be desirable for the responsibility for the complete training, for the full four of five years, to lie basically with the college ? To what extent is the college able to have, and to what extent is it desirable that the college should have, any impact on the two-and-a-half years spent in the factories in the six-monthly periods there ? This I regard as one of the biggest problems which we have to face.

   One of the ways in which the colleges are thinking that it may be desirable to develop the education leading to the Dip.Tech. award is the creation of a greater number of what may be called projects. A project is not a new thing to enlightened educationalists. I was talking only a few days ago to Professor Burstall, of Durham University, and he told me about some of the projects which he gives their B.Sc. students to do. The possibilities are very wide. They are a practical demonstration of a man's ability to understand his principles and to apply them to some particular thing. The project concept is going to be used increasingly by the colleges in order to get the right blend of theory and practice.

   It is possible that the college project will overlap into the six months period in industry, particularly in the last period of the scheme. How, then, can the project be arranged by the college if the college is not prepared to take, or if the company is not prepared to allow the college to take, the most intimate interest in the progress of the student in the works ?

   There are a few companies which have a very close understanding with the colleges. In the case of one college, for example, " homework ", in the sense of correspondence courses, is set weekly or fortnightly by the college, and the student during his six months in the works is expected to carry on this correspondence course. In my experience, however, the average college principal is frightened of this problem of contact with industry. He believes that he has a limited capacity to understand what is going on in industry once the student has gone back there, and that generally the industrialist will say " Mind your own business " and that he, the principal, is not fit or able to carry out the right degree of supervision once the student is back in the works.

The Integration of Practice and Theory

At the same time, we must realise that it is the integration of the practice and the theory which is important, and they cannot be looked on as separate bits of the sandwich or as being separated by a curtain, one from the other. The project is an example where the integration must be made complete by the very nature of the studies going on, and where the overlap must be an overlap in the true sense of the word. Yet how many managers in industry are prepared to let the college have the responsibilty over the five years ? Will they say : " While he is back in the works I must be given perfect freedom to put him on any job I like, and when he is with me I have to get the most out of him, whatever job comes up " ? My experience of college principals is that by and large they do not feel confident of their ability to control the student during his works-based period.

6. Is industry capable of training and willing to train more intensively during the industrial period ? Now that we have created this higher award, industry must raise its own sights

to fall in line with what we are creating and sponsoring. If the National Council is prepared to go to the existing colleges, on which you rely, and which may have a good name in your locality, and say to them, as we are doing in some cases, " We are sorry, but we do not think that you are good enough for this ", is it not a logical conclusion that we should go to the companies which surround such a college and possibly be forced to say : " We are sorry, but you are not good enough for what you want " ? I think that that is a logical conclusion, because we must regard the course as a complete period of training, and not as two entirely separate courses, the theoretical and the practical.

Is industry, therefore, prepared to raise its own sights and improve its own training facilities and efforts to the degree that the Hives Council demands from the colleges ? I do not know; I leave the question to you.

7. If industry is prepared to do that, what are the lines on which industry is prepared to do it ? What are the essential elements of industrial activity during the six months for which the student goes back to the factory? Many of us here served an apprenticeship. I am prepared to say a good deal about my own apprenticeship. I was very lucky in some ways in my teachers, but I am prepared to say definitely that much of the period that many apprentices spend is not apprenticeship in the true sense of learning effectively along the lines of what the Council has in mind.

What are we prepared to do about it ? How can we get industry to raise its sights ? What is practical training, in the sense of going back to the works ? What do we mean by it ? What sort of organisation is there in the companies for taking care of it ? What understanding of the theoretical work being done is present in the minds of those who control the apprentice when he is back on the job ? What are the essential ingredients of practical training ?

I have asked this series of questions, but I do not know many of the answers. I know the questions, and I have found very few people prepared to say in clear language " These are the answers that you should seek ".

The Greatest Single Problem

There is one other thing which worries me, and here I come right back to our Institution. I am your representative on the National Council. I think that I can state with fair emphasis that so far relatively few of us on the National Council have a clear idea of the training of the production engineer. Increasingly, however, that knowledge is becoming available and acceptable, and increasingly we shall get numbers of the chaps who come through this Dip.Tech. course and, who will be a credit to this Institution in the years that lie ahead. I am prepared to guess that a greater proportion of the Dip.Tech. award people in the next 10 years will become members of this Institution than of almost any other. Yet at the present time, if we bear in mind the requirements of production engineering and the things that have to be taught to these students, and if we bear in mind the composition of the staff of the various colleges, we shall find that the production quantum is lamentably low.

Let me take the example of a college which I visited recently, which is not very different from others. We went through the list of staff, bearing in mind that the staff have to be qualified in a variety of ways before we approve the college. When I looked at the number of those who had professional knowledge of production engineering, and of all the requirements which we regard as important, I was appalled. We know very well that the answer at the moment is : " We cannot get them. We cannot attract enough men with these abilities. We can get the man who has been through a university, but his knowledge of the requirements of the production and managerial future is very small indeed, and so we put up with people who have very little experience in these matters ". Many of the so-called production subjects in colleges are taught by people on the commercial and economic side.

What are we going to do about this ? I believe that this is one of the biggest single problems which we face, to encourage a greater amount of teaching talent with an understanding of production and of the essential requirements of the Dip.Tech. course. At the present time in the colleges of this country there is a lamentable shortage of that sort of person. How we can achieve all the things which I have said that we are trying to achieve in the Dip.Tech. courses ; how the colleges themselves can achieve and maintain this difference in the Dip.Tech. course which will distinguish it from anything else, without having a much more adequate number of teachers who have the sort of knowledge which we in this room possess, I do not know, and that is my final question to you.

AIRCRAFT PRODUCTION
CONFERENCE PROGRAMME

8th/9th JANUARY, 1957

Theme : " NEW MATERIALS — NEW METHODS "

(This Journal contains a report of **Session IV.** A report of **Sessions I, II** and **III** appeared in the March issue.)

SESSION I

Chairman : Sir Roy Fedden, M.B.E., D.Sc., Hon.F.R.Ae.S., M.I.Mech.E., F.R.S.A., Hon.F.I.A.S., Hon.F.S.A.W.E.

The Lord Sempill Paper

" CONCENTRATION OF AIRCRAFT DEVELOPMENT " by Karl Frydag.

SESSION II

Chairman : Professor E. J. Richards, M.A., B.Sc., F.R.Ae.S.

" FATIGUE OF AIRCRAFT " by Major P. L. Teed, A.R.S.M., M.I.M.M., F.R.Ae.S., F.I.M., F.R.S.A.

SESSION III

Chairman : J. B. Turner, M.I.Prod.E.

" NUMERICAL CONTROL OF MACHINE TOOLS IN AIRCRAFT MANUFACTURE " by O. S. Puckle, M.B.E., M.I.E.E.

SESSION IV

Chairman : S. P. Woodley, M.B.E.

1. **" THE HOT FORMING, ASSEMBLING AND SERVICE APPLICATIONS OF MAGNESIUM ALLOYS "** by R. G. Wilkinson, B.Sc.

2. **" RECENT ADVANCES IN THE APPLICATION OF RESISTANCE WELDING TO AIRFRAME CONSTRUCTION "** by N. K. Gardner, B.Sc.(Eng.), A.F.R.Ae.S.

3. **" CONTOUR ETCHING "** by A. W. Sheppard.

SUMMING UP

by H. G. Gregory, Chairman of the Institution's Council.

SESSION IV

THE HOT FORMING, ASSEMBLING AND SERVICE APPLICATIONS OF MAGNESIUM ALLOYS

by R. G. WILKINSON, B.Sc.

Mr. Wilkinson joined Magnesium Elektron Limited as a Research Metallurgist in 1940 *and was appointed Deputy Chief Metallurgist in* 1947, *Personal Assistant to the Assistant Managing Director in* 1952, *and Development Manager in* 1955. *He has specialised in work on wrought magnesium alloys and related production and fabrication, and has studied hot forming practices in the U.S.A. as well as in the U.K.*

He is Chairman of the Technical Panel of the Magnesium Industry Council and of certain Committees of the British Standards Institution.

THE Institute of Metals has recently published a detailed review(1) by the Author of the principles and practice of hot forming magnesium alloys. In the present Paper it has therefore seemed desirable — and appropriate to the spirit of this Conference — to attempt a brief survey of those main points of the subject which directly concern production and design engineers in the aeronautical and related fields, and which — it is hoped — may be in some cases of controversial interest. In particular, the Paper is intended to evoke expert discussion on a broad question which is naturally of some importance to the producer industry in its future planning and which, in their view, is of at least equal importance for consideration by their friends here.

The question is this:

Why is the proportionate usage of wrought to cast magnesium alloys in airframes, related equipment and guided weapons so much higher in the U.S.A. than in the U.K.?

In the U.K., wrought magnesium products have always averaged less than 10% of total output for engineering purposes. In the U.S., the proportion has been around 30% over the last few years and approached 50% in 1950 — a "Korean" peak in part due to extensive production of the Consolidated Vultee B-36 aircraft, each of which carries some 7,500 lb. of magnesium sheet (Fig. 1). It is true that the Americans use more wrought magnesium for general engineering purposes than we do, but obviously this factor can account for only some part of the contrast and we must look elsewhere for the governing reasons.

The U.S. aircraft industry is very large and has had more scope for experiment with relatively new materials or material forms, and this has encouraged enterprise and investment in the producer industries. The Dow Chemical Company and Brooks and Perkins Incorporated have led the field for many years in wrought magnesium fabrication development and in plant and personnel facilities for design, prototypes and production of sub-assemblies, as well as demonstration to aircraft companies wishing to do the work in their own shops. This is a "chicken or the egg" story in which the American "egg" has been hatched into a low-priced "bird", i.e., magnesium alloy sheet and extrusions have been produced in quantities much larger than here, and at correspondingly lower prices. This sheer scale effect has obviously had an important influence over the years in adjusting the proportion of wrought to cast products in America, but there must be other underlying considerations.

There are now firm signs in Britain that more attention is being paid to the potentialities of

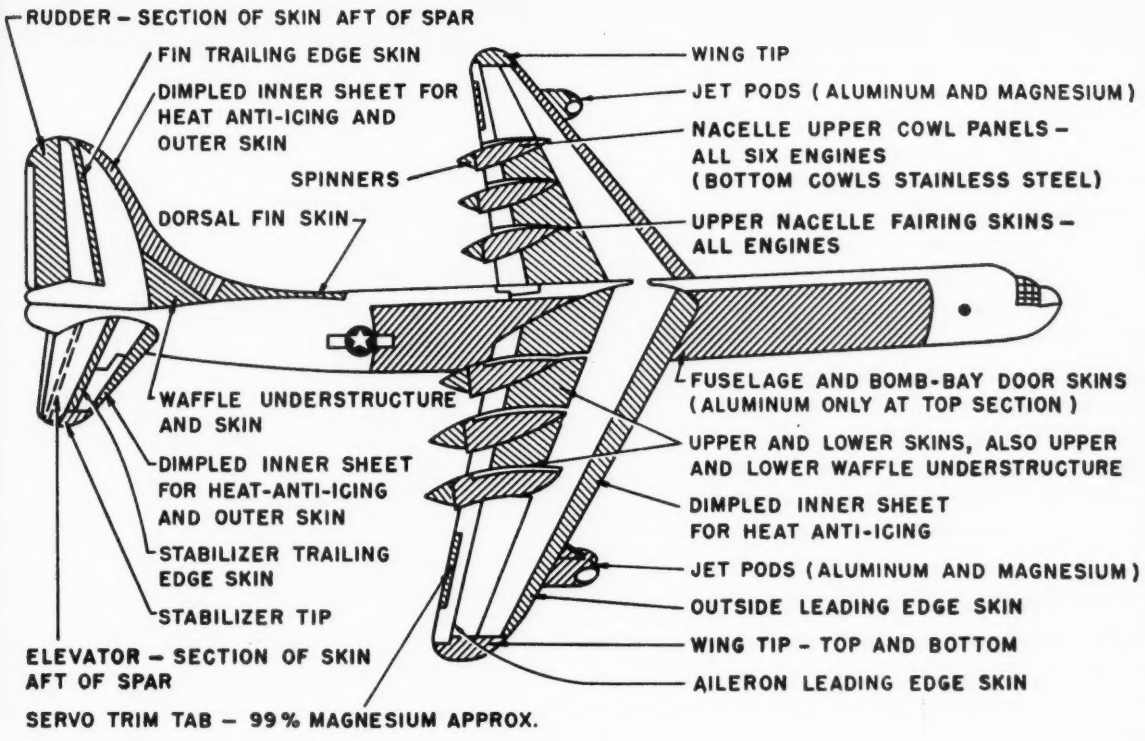

RUDDER – SECTION OF SKIN AFT OF SPAR
FIN TRAILING EDGE SKIN
DIMPLED INNER SHEET FOR HEAT ANTI-ICING AND OUTER SKIN
SPINNERS
DORSAL FIN SKIN
WAFFLE UNDERSTRUCTURE AND SKIN
DIMPLED INNER SHEET FOR HEAT-ANTI-ICING AND OUTER SKIN
STABILIZER TRAILING EDGE SKIN
STABILIZER TIP
ELEVATOR – SECTION OF SKIN AFT OF SPAR
SERVO TRIM TAB – 99% MAGNESIUM APPROX.
WING TIP
JET PODS (ALUMINUM AND MAGNESIUM)
NACELLE UPPER COWL PANELS – ALL SIX ENGINES (BOTTOM COWLS STAINLESS STEEL)
UPPER NACELLE FAIRING SKINS – ALL ENGINES
FUSELAGE AND BOMB-BAY DOOR SKINS (ALUMINUM ONLY AT TOP SECTION)
UPPER AND LOWER SKINS, ALSO UPPER AND LOWER WAFFLE UNDERSTRUCTURE
DIMPLED INNER SHEET FOR HEAT ANTI-ICING
JET PODS (ALUMINUM AND MAGNESIUM)
OUTSIDE LEADING EDGE SKIN
WING TIP – TOP AND BOTTOM
AILERON LEADING EDGE SKIN

Fig. 1. A total of 7,500 lb. of magnesium alloy sheet is used on the Consolidated Vultee B.36 bomber.

"simplicating and adding more lightness" by using wrought magnesium. However, one can rarely get something for nothing and this Paper will be an attempt to summarise the main pros and cons so that discussion may help to define the right "philosophy" of using wrought magnesium. With this in view, it will be useful to look at some aspects of assembly and surface protection methods, design factors and current applications, as well as the main theme of hot forming.

Detail will be avoided in favour of brief statements and illustrations of essentials — either way — with implied questions.

I
HOT FORMING

The following is a quotation from Reference (1): "Since all commercially available* magnesium alloys have a close-packed hexagonal crystal lattice, their capacity for cold deformation is limited. According to classical theory, above about 225°C. additional lattice slip planes become available for plastic deformation, and even below this temperature formability is improved. Thus, in producing severely formed sheet and extrusions, it is necessary to work hot, generally at temperatures between 230° and 350°C. This naturally involves provision of heating equipment for the material and tools, with attendant cost and some inconvenience. But once equipped for hot working and experienced in operations on magnesium alloys, the manufacturer gains important advantages as compared with cold forming other metals:

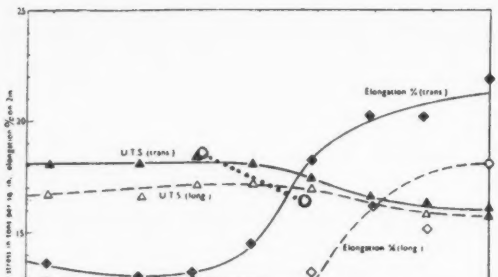
1. In most cases substantially greater deformation can be effected in one operation than is the case for other metals at normal temperature, thus avoiding additional tools and/or inter-annealing and forming operations.

2. Power requirements are reduced, so that a given shape can be made on a lower-capacity press, or a more difficult job can be made on a given press.

3. Because springback is reduced as forming temperatures are increased — becoming almost zero at the higher temperatures — dimensional accuracy is more easily attained.

4. It is often possible to control dimensions by suitable adjustment of temperature of tools and stock.

* Excluding certain magnesium-lithium alloys, which are body-centred cubic in structure.



(Courtesy of "Institute of Metals")

Fig. 2. Variation in mechanical properties of 18 s.w.g. sheet in ZW3 alloy after annealing for 30 min. at temperatures up to 400°C. The dotted lines are for FS 1 - H 24 sheet under the same conditions.

"Some magnesium forming operations can be satisfactorily completed in the cold, but these are limited to simple bending or shaping over (mainly uniaxial) contours of generous radii. However, it must be emphasized that the formability of heated magnesium alloys is very good, being at least as good as, and by some criteria better than, that of L70 aluminium alloy at room temperature. It is usually not difficult or very costly to provide heating on standard forming equipment, and in hand-forming, once operators have acquired the "feel" of the material under open-flame (e.g., blow-torch) heating, they often prefer to work hot for ease of forming, absence of springback, and freedom from cracking."

1. *Effect of Preheating on Mechanical Properties*

Magnesium alloy sheet derives much of its strength from "cold working" in the rolling operation; it is not heat treatable in the aluminium alloy sense. Therefore, preheating before forming naturally acts to some extent as a "letting-down" anneal. Fig. 2 shows the effect for the half hard magnesium-3% zinc-0.7% zirconium alloy ZW3 (D.T.D. 626A) and for American hard rolled magnesium-3% aluminium-1% zinc FSI-H. 24. The superiority of the zirconium-containing alloy will be evident, since the "residual" properties are higher. The curves apply to 30 min. preheating time at temperatures up to 400°C. Typical practice is to preheat for up to 15 min. at about 300°C.

In the shop, avoidance of conventional heat treatment as for aluminium to some extent mitigates the need to preheat magnesium for forming.

2. *Preforming Operations*

(a) *Condition and Storage of Sheet*

If hot forming is to be severe — e.g., as in deep drawing — the sheet should be purchased in the unchromated condition since the graphitic lubricant normally used in such cases is difficult to remove from a chromated surface.

Because *unprotected* magnesium is susceptible to corrosion in *contaminating* environments (e.g., liquors from brown paper or wood, acid-salt-laden dust, cathodic particles in stagnant aqueous media), storage of sheet should be under good conditions as for other metals.

(b) *Cutting of Sheet or Blank Preparation*

Guillotine cutting up to 0.080" is entirely satisfactory, but for thicker material routing is essential for best results in avoiding a rough, flaky edge. Similar limitations apply to punching and blanking. Of course, if a trimming operation can be carried out by routing after forming, these limitations do not apply.

There are special recommendations for shearing, punching or blanking tool design which will give greater latitude with magnesium and which will permit working up to 0.160" thickness.

Fixed-head or radial-arm routers can be operated up to speeds of at least 20,000 r.p.m. and will cut single or stacked sheet thicknesses of up to $\frac{3}{16}$" without burr. Heavy plate should be sawn.

It is well-known that magnesium "fines" can be a fire hazard, and the precautions in tool design and good-housekeeping need not be detailed.

(c) *Preheating*

For hand forming, gas-torch heating of sheet *in situ* with tools is normal, with control by temperature-indicating crayons or other convenient means.

For flat blanks, a gas or electric platen heater is quickest and best. Where shapes have to be preheated a gas or electric oven is necessary and should be mounted on wheels for flexibility.

There is no oxidation or firing problem, because preheating temperatures rarely exceed 370°C.

In certain forming operations, resistance heating is used.

(d) *Tools*

The main point here is that the most economic tool material capable of withstanding temperatures of around 300°C. should be used, having regard to the length of run. Table I shows the normal materials and, although the Table does not perhaps bring out the point, it should be emphasised that for small/medium quantities off, the use of magnesium alloy tools can show dividends.

For heavy-duty work over a long period, magnesium does not possess the requisite wear resistance and it is then usual to adopt a steel, but for the quantities customary in the British aircraft industry there can be little doubt that magnesium can be used in many cases.

The outstanding machinability of magnesium helps to speed tool manufacture and to minimise costs. Also, it is obviously of advantage in relation to differential expansion to use a tool of the same material as the work because no expansion/contraction factors need be allowed.

(e) *Forming Lubricants*

It can be taken as a general rule—to date—that a graphitic lubricant is required for severe work and that this will be difficult to remove after forming. Removal depends essentially upon use of a chromic acid solution which has a definite nuisance value.

However, for more usual forming operations in the aircraft industry it is normal to use waxes or high-temperature oils at temperatures up to 300°C. These are more easily removed.

Lubricants have been included in this section because it is sometimes necessary to pretreat a blank with lubricant before it enters the machine.

3. *Forming*

It is now well established, with few exceptions, that if the operative will once accustom himself to work hot he will be able to achieve with magnesium that which he does every day with aluminium. And he can often achieve more severe deformations in single operations.

Cold forming should only be considered for large-radius (uniaxial) bending, e.g., for bending roll work. But beware of springback or cold cracking if the radius is marginal, i.e., 5/10T.

It would be a duplication to deal here in detail with all the various conventional machine forming operations as applied to magnesium. The Author hopes that it may suffice for him to repeat, and to show by some examples, that once work and tool heating have been laid on, anything which can be done with aluminium cold, or more, can usually be done with magnesium. If an operative is working with a cold metal, he knows when to stop. It is the same with hot magnesium. It is true that if the operative starts to "feel" the metal stiff, he must apply, or ask for, some more heat from the blow-torch, and to this extent he is at a disadvantage from his colleague working a cold metal. But that colleague may have to send his work-piece back to the annealing oven for some time before he can resume forming, whereas the magnesium man can "turn on the heat" and finish the job on time.

It cannot be too strongly emphasised what flexibility of operation is conduced by the use of heat.

As yet, in the U.K., there are not very large production quantities of the articles dealt with in this

TABLE I

Tool Materials for Forming Magnesium Alloys

Tool Material	*Remarks*
Tool Steels	All relatively costly and used only for longest runs.
Chromium-plated or nitrided steels	Good in diminishing pick-up.
Meehanite cast iron	Good in reducing cost of machining and polishing the dies.
Mild Steel	The usual material for pressure plates and draw rings, and sometimes for punches. Must be stress-relieved for one hour at 650°C. and air-cooled before finish-machining to avoid distortion in service.
Cast iron Aluminium alloy Magnesium alloy	With steel, the usual materials for punches. Magnesium usually best because of easy machinability, lightness for handling, and no differential expansion ; very good for rubber-press tools.
Kirksite (high-purity zinc-base alloy containing aluminium and copper)	Often used for stretch-forming blocks and for short-run female dies in drop-hammer work. Tends to soften and spread in service.
Antimonial lead	Only used for drop-hammer punches.
Concrete Plaster	Sometimes used for stretch-forming blocks protected by glass-fibre cloth.

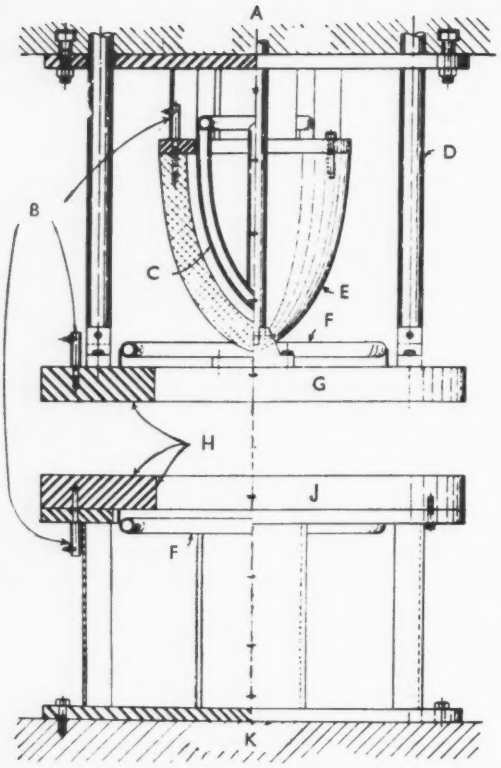


Fig. 3. Typical die set-up for hot drawing magnesium alloy sheet (after Winkler). Key : A—main ram ; B—thermocouple connections ; C—gas burner pipe ; D—pressure pins to clamp rams ; E—male die ; F—pipe-ring burner; G—pressure ring; H—polished surfaces ; J — draw ring ; K — bolster plate.

(Courtesy American Society for Metals)

Paper and, therefore, a good deal of hand work is used. If, for example, a deep box is required, then this is made by cutting, hand bending over a magnesium form block and Argonarc welding sheet, with the design radii based on later potential production on the deep-drawing press.

It has been indicated that there is an ultimate limit of 5T for cold bending and that 10T is more usual. These are 90° values. The corresponding figures for hot working are 1T — 4T for the materials produced in this country. (For hard rolled material in the U.S.A. these figures are roughly doubled.)

Sheet-bending roll work requires no comment, and press-braking of magnesium presents no difficulty, using steel male and female dies or a steel male die dropping into rubber contained in a U-shaped lower die. In the former case both dies are heated, and in the latter only the upper tool. Electrical-strip heaters are ideal for die heating, preferably in conjunction with automatic temperature control. For long bends it is helpful to use hot sheet with cold tools, and to allow the bend to dwell in the tools to achieve stable desired shape.

It may be useful now to comment on the effect of varying forming speed. The average press brake is of relatively quick action (30 - 40 strokes/min.), and this is perfectly satisfactory for magnesium with a 90° bending radius down to 1T. In general, however, even more severe deformation can be effected at slower speeds ; e.g., at 320°C. and with a closing speed of 1″/min., annealed sheet can be bent and flattened through 180° with no radius and no cracking. This is an extreme example, but indicates what can be done with an hydraulic press with speeds of up to 4′/min.

In stretch forming, which is essentially a tensional process, operating temperatures of 130°C. - 180°C. are used in the interests of adequate tensile strength to avoid excessive elongation and fracture. Even at these relatively low temperatures, however, differential stretch values of up to 15% are obtainable with excellent contour control and no springback for convex contours of 20′ radius or less. The use of fibre-glass blanket between the sheet and the form block (usually Kirksite), with a little differential lubrication with mineral oil, has been found beneficial. The form block should be heated internally by electrical elements, and friction-type grips are necessary.

Fielding has recently given a detailed account (2) of the rubber pressing of magnesium, and the following is a quotation of his conclusion :

"Although the deformation possible with magnesium alloys is very limited at room temperature, the situation is completely changed if the blank and dies are heated to 300°C. When pressed hot, magnesium alloys may be subjected to extreme deformation without the appearance of undesirable effects. Where stretching is involved on concave flanges, or flanged holes, magnesium alloys will take much more deformation than aluminium alloys. In addition, the components produced are of exactly the required shape and are not distorted in any way, as is often the case with aluminium alloys at high percentage deformation. As regards shrinking, magnesium alloys again compare very favourably with aluminium alloys, and appreciably more working is possible before the onset of wrinkling Hot pressing is, however, more expensive, more complicated, and requires a rather higher class of labour."

Permissible design deformations are :-

Flange radii : 2 - 5T minimum, according to temperature, gauge, and difficulty of job.

Stretch flanges : commonly 25% maximum, but often higher and at least 57% on full-circle flanges.

Shrink flanges : 3% - 5% without reliefs, the higher with higher temperature and thicker sheet.

Beads : for internal beads the minimum width : height ratio is 4 ; external beads are easier.

Hydraulic pressures of 800-1,200 lb./in.² are usual : magnesium form blocks are very satisfactory, heated either *in situ* or separately together with the sheet : but special rubbers which do not deteriorate too rapidly at operating temperatures have to be used,

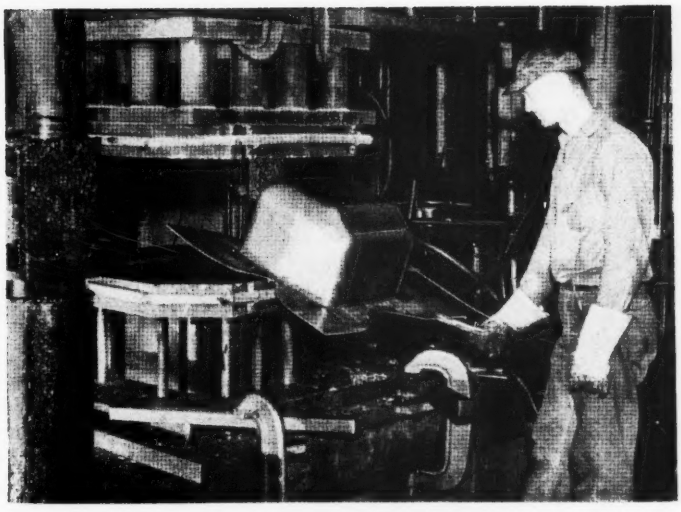


Fig. 4. Single stroke deep drawing operation on magnesium alloy sheet.

either for the whole pad or as a 1" blanket shielding the normal rubber from the hot work.

Figs. 3 - 5 give an indication of the practice and possibilities of magnesium deep drawing, its capacity for which is exceptional. *Single* draws to a depth of three to four times that for cold steel or aluminium can be made. Design data are :-

Draw-ring radius	4T - 7T
Punch-bottom radius ...	3T min. - 10T
Drawability for cylindrical cups	
$\frac{\text{Blank dia. - Cup dia.}}{\text{Blank dia.}}$	0.7 max.
Depth : dia. ratio for cylindrical cups	2 max.

For rectangular boxes, depth should preferably not exceed 12 times the corner radius.

Hydraulic presses have been mainly used for die pressing or deep drawing, but recently mechanical presses with speeds in excess of 60'/min. have been found suitable provided they are fitted with die cushions. Indeed, in certain cases a quick-acting press is better in restricting cooling of the blank and in avoiding puckering. Drawing pressures are always lower than those required for aluminium.

Hammer forming is an exception to the nearly general rule that hot magnesium can be deformed as severely, or more severely than, cold aluminium. Still, however, recent experience has shown that shallow, high area forms can be made by this process quite successfully, with fewer stages and reduced springback and shrinkage wrinking than for L70 aluminium alloy.

Fig. 6 shows a typical drop hammer magnesium component.

All forms that can be spun cold in *pure* aluminium can be spun in magnesium at 250°C. - 350°C., with little difference in technique apart from heating which is usually by gas blow-torches. Magnesium formers are recommended for short runs.

Fig. 5. Single stroke, deep drawn cover in magnesium alloy sheet, showing method of stiffening.

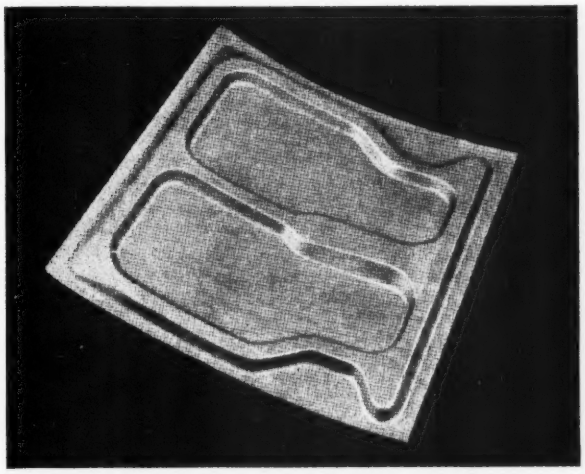


Fig. 6. Inner skin for aircraft door, showing type of magnesium alloy component made on a drop hammer. ***(Courtesy " Tool Engineer.")***

For more detail, readers are advised to see Ref. (1) which includes an embracing Bibliography.

II
SURFACE PROTECTION AND ASSEMBLY

It has been indicated that if there is an incentive to use a relatively unfamiliar material to "simplicate and add more lightness", there are at least some dividends to be recovered by working hot. There are also nuisances in working hot, but we cannot often avoid certain nuisances in such circumstances. One of the troubles here is to tolerate yet another new material in the press and assembly shops. The introduction of such a new material — together with the need for heating for forming — causes some temporary difficulty in establishing practices and inspection. But, it is submitted, this difficulty will be forgotten after a few months when the Company's aircraft or article of aircraft or airborne equipment has been shown to be lighter, stiffer and more efficient than that manufactured by its competitors. There is no plea here for magnesium to be adopted immediately for the primary structure of British aircraft. But there is a plea for magnesium to be tried *experimentally* for primary structure in the same way as has been successfully explored with the F-80C in America (Section III). *Above all, there is a hope that this Conference will say why, or why not, the basic principles of using ultra light, weldable magnesium, should be applied more extensively for secondary or lightly stressed internal structures, together with airborne auxiliary equipment.*

It may be thought that the foregoing paragraphs would be better placed in the last Section of this Paper devoted to design and applications, and the basic principles will indeed be elaborated there. However, the Author has found from experience that production engineers are reluctant to introduce new materials with "nuisance values" into their shops unless they are compelled to do so. He has, therefore, added these notes to ask them to look at some of the examples later and to add their voices to those of designers in advising the magnesium producing industry of the prospects of building more efficient aeroplanes or equipment by using more magnesium.

Designers and production engineers will undoubtedly wish to be satisfied that there is justification for introducing more magnesium. Wrought magnesium is more expensive than aluminium and its forming and assembly at present cost somewhat more. But the conclusions in the S.B.A.C. Document "The Financial Aspect of Weight Saving" (3) are as follows:

"It is safe to say that it is well worth spending £35 to save one pound in weight. This figure is almost invariably less than the weight saving is worth to an operator in two years (as has been shown), and it should be remembered that the aircraft will probably be in first line use for eight years. Such reasoning applies to a modern transport aircraft with comprehensive equipment.

Clearly it would probably be economic to spend up to two or three hundred pounds per pound weight saved. What can actually be done depends on how prohibitive the resulting increase in first cost appears to the aircraft operator.

It is hoped that this report will serve as a useful guide to the amount of money it is worth spending to reduce the weight of any item. It should be noted, however, that the calculations have been made for a representative set of conditions and adjustments should be made for particular cases."

The S.B.A.C. comments, somewhat dryly, on weight saving in military aircraft:

"The fact that only civil aircraft are dealt with here does not mean that weight saving on military types is any less important. The Society does not, however, presume to try and assess in £. s. d. the value to the country of having aircraft of the highest performance."

Heinemann (4) quotes similar figures, and then comments:

"From these figures it can be seen that there is ample justification for the expenditure of engineering time on all phases of a weight saving program, no matter how small the individual saving may seem."

The production engineer is asked to consider going out of his way to assure his company's designers that he can cope with the introduction of some additional and, perhaps in a few cases, unfamiliar operations on magnesium.

1. *Surface Protection*

Magnesium has been used in aircraft for over 30 years. Following progressive improvements in alloy purity and quality, as well as better understanding of design and assembly methods, it has a good service record, that is apart from some cases of malpractice and/or misapplication. However, operating conditions have now become more severe, especially in high flying, pressurised aircraft where inaccessible components often have to operate in wells of accumulated condensate. For military or economic reasons, modern civil or Service aircraft not only have to be as efficient as possible, but also have to need the minimum of inspection and maintenance. Guided weapons have to be capable of functioning after long periods of what may sometimes be storage in imperfect conditions.

To meet this situation, new protective treatments and finishes have been introduced in the U.S.A. and the U.K. These supplement, or in some cases replace, the "classical" chromating.

The American processes are the H.A.E. (5) and CR-22 (6) (both developed by Frankfort Arsenal), and the Dow Chemical Co. No. 17 (7). All are electrolytic treatments and give relatively thick, porous films which can absorb waxes, lacquers, etc., for sealing purposes. The H.A.E. film is very hard and brittle; it can spall badly and has a considerably adverse effect on the fatigue resistance of the metal. Nevertheless, a sizeable piece of American airborne equipment so protected has now been in satisfactory service for some years under conditions always involving intermittent drenching in sea water. No doubt field maintenance has been thorough.

In Britain, Magnesium Elektron Ltd. has introduced Fluoride Anodising and Surface Sealing, due to Higgins (8). The first treatment is completely effective in removing any cathodic impurities or contaminants (e.g., iron), thus producing a thoroughly clean surface of maximum intrinsic corrosion resistance. Surface Sealing is applied after anodising and chromating, and depends upon the use of a stoved epoxy resin of particular characteristics which cause it to adhere to magnesium better than any other known substance, and also to possess a high degree of impermeability to water. The method of application is important, and it should be noted that to date — of all epoxy resins tested — only unadulterated Araldite 985E has been found to give standard results.

These two M.E.L. processes are now finding encouraging acceptance in the aircraft and other industries, and have been approved under D.T.D. 911B of July, 1956. A new D.T.D. Specification is in draft for Surface Sealing. Normal aircraft approved paint schemes are, of course, applied over the sealed surface.

It is not claimed that any of these schemes is the eternal panacea, but they represent a very significant advance.

To counter bi-metallic corrosion, wet assembly using a chromate-bearing compound to D.T.D. 369A, and the incorporation of insulating strips or washers, are well known. And they are very effective when properly applied.

Finally, in this Section, there is a plea to the designer. Whatever the metal, design for corrosion-trouble-freedom and try to make quite sure that *all draughtsmen* really know that :

(i) If no aqueous liquid can intrude, there can be no corrosion, bi-metallic or otherwise. Therefore seal.

(ii) If it must intrude, "design away" stagnant liquid by avoiding pockets, providing drains and spreading the bi-metallic current path by using generous insulating fillets.

Present company is excepted and it may, therefore, be surprising to the Conference that the Author has met more than a few senior designers, technicians and production engineers who were in some cases quite ignorant, and in others incompletely cognisant, of these basic points. Their neglect, when we are trying to build fewer aircraft of better quality, cannot be condoned.

2. *Joining Methods*

Before looking briefly at the various methods, let it be recognised that whatever the joint, *and whichever the light metal*, initial design and assembly workmanship should look after the avoidance of unnecessary stress concentrations. Magnesium is, perhaps, comparable to the highest strength aluminium base wrought alloys in notch fatigue sensitivity. Therefore, mechanical or welded joints in magnesium should be designed and effected to minimise stress raisers. This is the most important single factor in assembly to ensure mechanical serviceability.

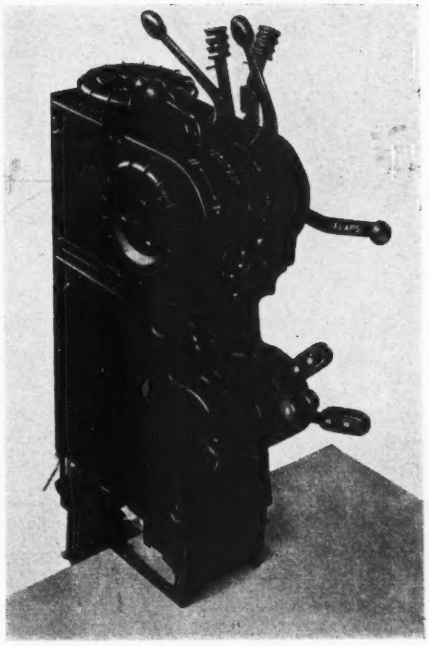


Fig. 7. Engine and trim control pedestal for the Scottish Aviation "Twin Pioneer". Sheet pressings in ZW3 aolloy. Weight 11 lb. 13 oz. ***(Courtesy Scottish Aviation Ltd., and Teleflex Products Ltd).***

(a) *Mechanical Joints*

Screws and bolts should be of cadmium plated steel if the joints are heavily stressed.

For lightly stressed bolts and rivets, MG5 (L58) or Duralumin (L57) should be used. L58 is better from a bi-metallic corrosion angle, but in practice there is now a growing tendency to use the stronger and more reliable L57 rivet combined with adequate wet assembly protective methods and vigilance against cracking of the sheet through higher closing pressures.

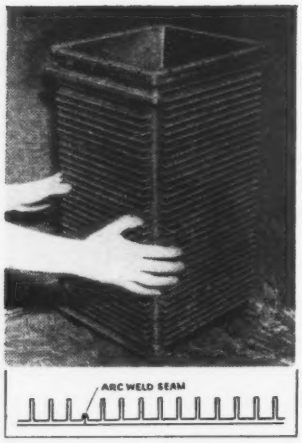
Rivet diameter should be at maximum three times sheet thickness, or at least equal to the thickness of thick plate, or of the thicker with plates of unequal thickness. Distance between centres should be three times rivet diameter, and minimum edge distance twice rivet diameter. Holes should be drilled or reamed, and rivets should be squeezed. For flush riveting, drill counter sinking is satisfactory down to 16 s.w.g. ; for thinner material, hot dimpling is used.

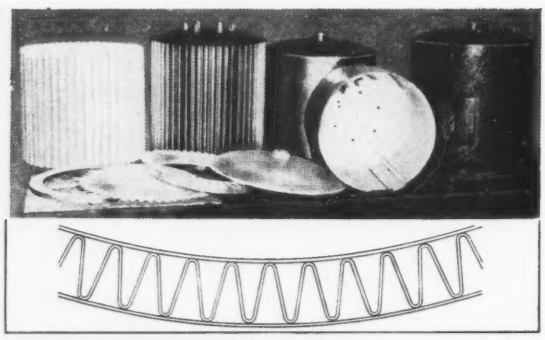
Fig. 7 shows a typical mechanical assembly of sheet pressings.

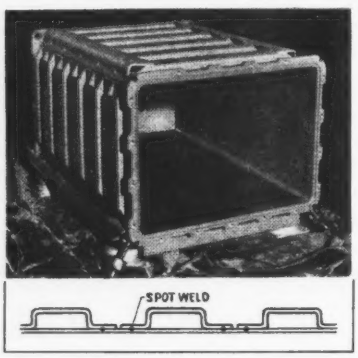
(b) *Welded Joints*

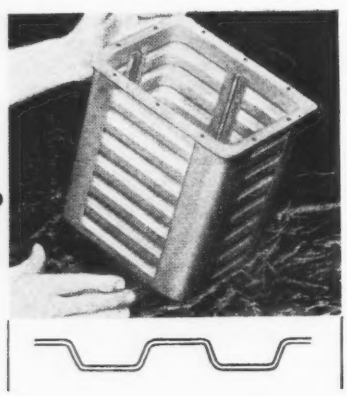
Argonarc welding is undoubtedly superior to oxy-acetylene welding because :

(i) It is applicable to all weldable magnesium alloys — and most are weldable. Oxy-acetylene welding









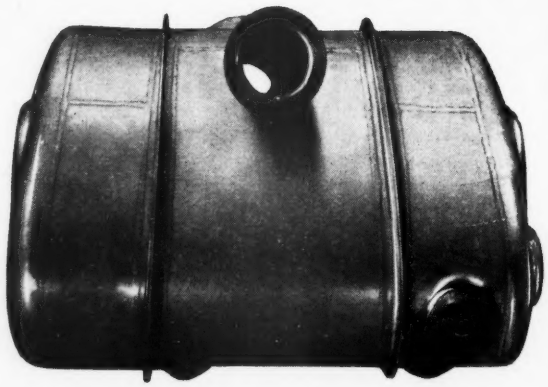


Fig. 8. Oil tank for "Twin Pioneer", oxy-acetylene welded in AM503 alloy. Weight: 6 lb. 15 oz. ***(Courtesy Scottish Aviation Ltd.).***

Fig. 9 ***(left).*** **Four ways of fabricating magnesium pressurised containers for electronic equipment: A. all extrusions; B. three sheet metal cans; C. sheet with extrusions; D. corrugated sheets.**

is only permissible for the lower strength wrought alloys and never for those containing zirconium.

(ii) Weld strength efficiencies (typical 75%) with Argonarc welding are always higher because of purely metallographic considerations as well as greater uniformity of quality.

(iii) No flux is used in Argonarc welding, so that post-welding (and troublesome) cleaning operations are not required.

Universal Argonarc weldability of nearly all the highest strength magnesium alloys — *wrought to cast as well as wrought to wrought* — is an important factor in choosing a material to make stiff, economical and reliable structures. However, after many years of the practice, for such envelope structures as fuel tanks, oxy-acetylene welding is even now still used (Fig. 8), although it is probable that for this type of work Argonarc welding will be adopted for future models.

Figs. 9 and 10 illustrate typical American and British welded magnesium alloy applications.

Argonarc welding equipments and techniques are now well known, but it may be worth noting that there have been recent improvements in applying these to thinner sheets of the order of 18 - 20 s.w.g.

For all high strength alloys, welded structures should be stress relieved, and this can often be conveniently combined with stoving at 200°C. for Surface Sealing.

(c) *Spot Welding*

Spot welding of magnesium is used extensively in the U.S.A., with shear strengths of single spots ranging from about 200 - 1,300 p.s.i. for sheet thicknesses of 18 - 10 s.w.g., respectively. Its utility for subsidiary structures is obvious.

Fig. 10. Radio station structure in Argonarc welded ZW1 alloy for a British airliner.

(Courtesy Marconi Ltd. and D. Napier & Sons Ltd.).

(d) *Adhesive Bonding*

Fig. 1 showed the use of 7,500 lb. of magnesium sheet in the B-36 bomber, and many assemblies in this aircraft made use of Metlbond. It must be said, however, that in this country there is as yet little accumulated experience of the use of Redux and Araldite on magnesium. Experimental results have shown that shear strengths realisable with magnesium fall far short of those for aluminium, although they are adequate for many lightly stressed applications, especially with the judicious use of one or two rivets to guard against rather low peel strengths. Adhesive bonds do, however, exclude moisture from faying surfaces.

III

SOME DESIGN INCENTIVES

The chemical compositions and principal mechanical properties at normal temperature of British wrought magnesium alloys are given in Table II. American alloys are similar and have similar properties.

Fig. 11 shows one of the production lines of Boeing B-47 magnesium tail cones at one of the factories of Brooks and Perkins Inc. Manufacturing operations include rolling the sheet, deep drawing, rubber press forming, stretch forming, press braking, drilling, riveting, chromating and painting. Weight saving

TABLE II

Mechanical Properties and Chemical Compositions of Magnesium Wrought Alloys

Typical Chemical Composition				Alloy	Specification	Tensile Properties			Compressive Properties		Hardness
Al. (%)	Zn. (%)	Mn. (%)	Zr. (%)			0.1%(1) Proof Stress (t.s.i.)	Ultimate Stress (t.s.i.)	Elongation (% on (2in.)	0.1%(1) Proof Stress (t.s.i.)	Ultimate Stress (t.s.i.)	Vickers
				ZW3: Sheet ≥ 18 S.W.G.	D.T.D. 626A	11.0-14.0	17.0-20.0	8-18(3)	9.0-10.5	—	60-70
				ZW3: Sheet < 18 S.W.G.	D.T.D. 626A	10.0-12.0	16.0-18.0	(3)	N.D.(4)	—	60-70
	3.0		0.7	ZW3: Solid extrusions > 0.375in. and up to 4in.	D.T.D. 622A	14.0-17.0	20.0-23.0	10-25	12.0-15.0	25.0-30.0	65-75
				ZW3: Solid extrusions ≤ 0.375in.	D.T.D. 622A	12.0-15.0	18.0-21.0	10-15	N.D.	—	65-75
				ZW3: Press forgings(5)	D.T.D. 619	13.0-15.0	19.0-22.0	8-14	10.0-13.0	24.0-28.0	60-80
				ZW3: Impact forgings(5)	D.T.D. 729	11.0-14.0	17.0-20.0	8-12	9.0-12.0	24.0-26.0	60-80
				ZW1: Sheet ≥ 18 S.W.G.	D.T.D. 5001	10.0-12.0	16.0-18.0	8-18(3)	N.D.	—	60-70
				ZW1: Sheet < 18 S.W.G.	D.T.D. 5001	9.0-11.0	15.0-17.0	(3)	N.D.	—	55-65
	— 1.3		0.7	ZW1: Solid extrusions > 0.375in. and up to 2in.	D.T.D. 5011	11.0-14.0	17.0-20.0	10-20	10-13	19-24	60-75
				ZW1: Solid extrusions ≤ 0.375in.	D.T.D. 5011	10.0-12.0	16.0-18.0	10-15	N.D.	—	60-75
				ZW1: Extruded tube	D.T.D. 5021	11.0-14.0(2)	16.0-20.0	4-15	N.D.	—	N.D.
	5.5		0.7	ZW6: Extrusions: as extruded	D.T.D. 5031	13.0	19.0	10	N.D.	N.D.	N.D.
				ZW6: Extruded and heat-treated	D.T.D. 5041	14.0	20.0	8			
				AM503: Plate, sheet and strip	D.T.D. 118A / B.S. 1353 (Gen. Eng.)	4.0-10.0	13.0-18.0	5-14(3)	N.D.	—	35-45
		1.5		AM503: Extruded bars and sections	D.T.D. 142A / B.S. 1355 (Gen. Eng.)	8.0-13.0	15.0-20.0	4-10	6.5- 8.5	20.0-23.0	45-55
				AM503: Extruded tube	D.T.D. 737 / B.S. 1357 (Gen. Eng.)	9.0-11.0(2)	15.0-17.0	4- 6	N.D.	—	45-55
3.0	1.0	0.3		AZ31 (high purity): Plate, sheet and strip, Half hard	D.T.D. 742	10.0	16.0	8(4)	N.D.	—	N.D.
				AZ31 (high purity): Plate, sheet and strip, Soft annealed	D.T.D. 732	—	14.0 min.-17.0 max.	12(4)			
				AZM: Extruded bars and sections < 3in.	D.T.D. 259A / B.S. 1354 (Gen. Eng.)	11.0-14.0	17.0-22.0	10-18	8.0-11.0	24.0-27.0	60-70
				AZM: Extruded bars and sections > 3in.	D.T.D. 749 / B.S. 1354 (Gen. Eng.)	9.0-12.0	14.0-19.0	8-16	7.0-10.0	22.0-26.0	55-65
6.0	1.0	0.3		AZM: Extruded tube	D.T.D. 348A / B.S. 1356 (Gen. Eng.)	10.0-12.0(2)	17.0-20.0	8-12	8.0-11.0	—	60-70
				AZM: Forgings(5)	D.T.D. 88C / B.S. 1351 (Gen. Eng.)	10.0-13.0	18.0-20.0	8-14	8.0-10.0	22.0-26.0	60-70
8.0	0.4	0.3		AZ855: Press forgings(5)	D.T.D. 88C / B.S. 1351 (Gen. Eng.)	10.0-14.0	18.0-22.0	8-14	10.0-13.0	25.0-30.0	65-75

1 Proof stress by " offset " method
2 0.2% proof stress
3 12 S.W.G. and thinner: 180° cold bend, 8T
4 12 S.W.G. and thinner: 180° cold bend 6½T (half hard), 3½T (soft annealed)
5 Forging properties quoted are those in the most favourable direction of flow: the manufacturer should be consulted on directionality
6 Not determined

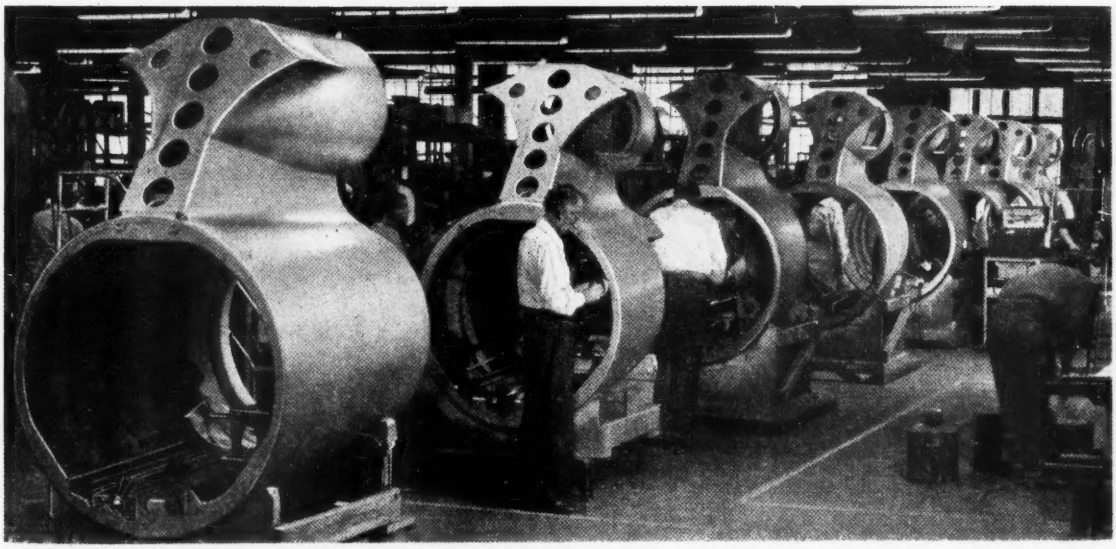


Fig. 11. Brooks and Perkins Inc. assembly line for Boeing B.47 tail cones.

figures are not available, but they must be worthwhile, since it is known that magnesium sheet is also used in similar applications on the B-52.

The main incentive to adopt wrought magnesium is, of course, to achieve stiffness. The elastic modulus of magnesium is about 6.5×10^6 lb./sq. in. against 10×10^6 lb/sq. in. for aluminium and 30×10^6 lb./sq. in. for steel. Therefore, it is necessary to stiffen parts in magnesium which are replacing parts in aluminium or steel that have been stressed to given deflection limits. With castings this arises only seldom for practical reasons of minimum castable wall thickness. But for extrusions and sheet the moment of inertia must be increased. This increases in proportion to the cube of the depth of section *or thickness of the sheet*, and only in linear proportion to width. Therefore, with the low specific gravity of magnesium (1.8) it is clear that weight saving and/or greater stiffness can easily be achieved providing there is room to increase sections. There is usually ample room to increase the thickness of a sheet!

This brings us to Figs. 12 - 15 showing the East Coast Aeronautics Inc. version of the Lockheed F-80 in comparison with the production aircraft in aluminium. In a Paper to the Annual Meeting of the Institute of Aeronautical Sciencies in 1955, Garges (9) refers to the following points :

"(i) Both the conventional aluminium alloy wing and the magnesium wing utilise a two-spar type of construction and weigh approximately the same. The aluminium wing distributes the spanwise bending loads in proportions of about 66% in the spar caps and 34% in the skin and stiffeners. The magnesium wing reverses this procedure and absorbs only 34% of the bending loads in the spar caps and 66% in the sheet skin alone, since it has no stiffeners. The heaviest skin gauge on the original wing was .051". The magnesium wing utilised skin from .064" to .375".

(ii) Simplification of design and reduction in numbers of parts and fastenings, with consequent reduction in numbers of drawings, manufacturing tooling and labour.

(iii) Smoother aerodynamic contours through the use of thick skins, with a 5 knot increase in top speed in the first aircraft fitted only with magnesium wings. Additionally, the use of thick skins allows drill counter sinking instead of dimpling, and eliminates fatigue cracking of thin sheet around rivets.

(iv) An increase in internal fuel capacity in the wings.

(v) An increase in torsional rigidity of the wing of around 50%."

Garges also mentions the high resistance of thick magnesium to buckling. A working exhibit to be shown at the Conference demonstrates its superiority over aluminium for non-buckling shear panels. Although the magnesium panel is only 71% the weight of the aluminium panel, it will withstand a higher shear load before buckling commences. This superiority applies for all normal values of shear flow, but for very high values, D.T.D. 687 aluminium alloy has been found better than magnesium. The exhibit was devised by a well known British aircraft company who are using large quantities of magnesium sheet.

For guided missiles and supersonic aircraft subject to aerodynamic heating, entirely new magnesium sheet and extrusion alloys are now becoming available following intensive work on the magnesium-thorium-zinc-zirconium and other alloy systems. These researches resulted some years ago in the commercial introduction of the creep resistant casting alloy ZT1 (D.T.D. 5005) which is designed for engine service up to 350°C. In the U.S.A., a magnesium-3% thorium-

TABLE III Representative Mechanical Properties of New High Temperature Wrought Magnesium Alloys

	0.1% *Proof Stress t.s.i.*	*Ultimate Tensile Stress t.s.i.*	*Elongation % on 2"*
Normal temperature tensile properties	10	16	12
Creep Resistance	0.1% creep strain at 4 t.s.i. after 100 hours at 250°C.		
	0.25% creep strain at 5 t.s.i. after 500 hours at 250°C.		
Young's Modulus	5.5×10^6 p.s.i. at 250°C.		
	5.3×10^6 p.s.i. at 300°C.		

0.6% zirconium alloy HK31 has been introduced by the Dow Chemical Company and is now in experimental service. The same Company has another alloy under development; this has a composition magnesium-2% thorium-1% manganese and shows promise of being a further improvement. In the U.K., M.E.L.'s work has shown a magnesium-2.7% thorium-1% zinc-0.7% zirconium alloy, ZTX, to be better than HK31, and it is hoped to make it commercially available soon.

Table III gives some typical figures to illustrate the order of mechanical properties. Further data will be presented at the Conference.

The magnesium industry will be grateful to have comments on the usefulness of such properties, and in this connection the high specific stiffness of the alloys up to 300°C. will, perhaps, be noted.

Acknowledgments

In addition to the acknowledgments made in the text and references, the Author wishes to thank the Chairman and Directors of Magnesium Elektron Limited for permission to present this Paper. He also wishes to thank some of his colleagues for their kind advice and help in various directions.

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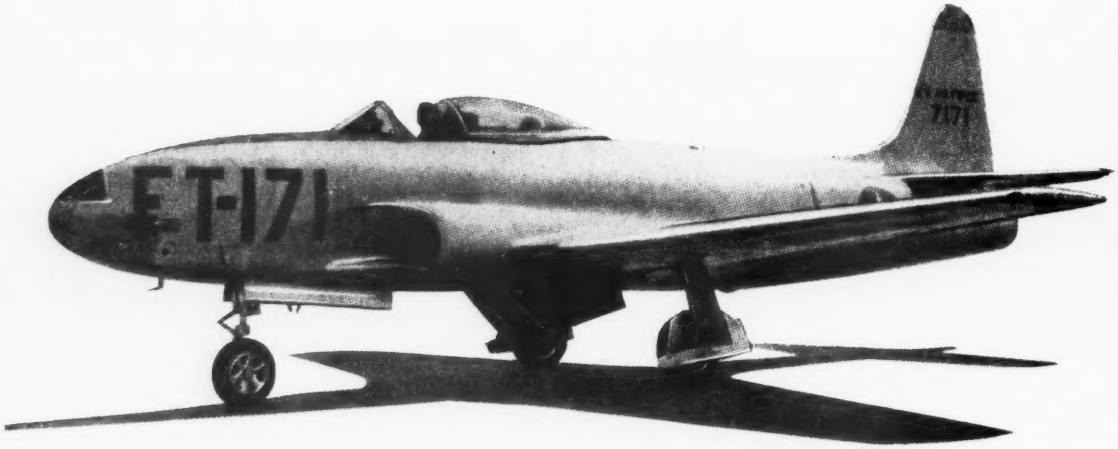


Fig. 12. The "all magnesium" Lockheed F-80C manufactured by East Coast Aeronautics Inc.

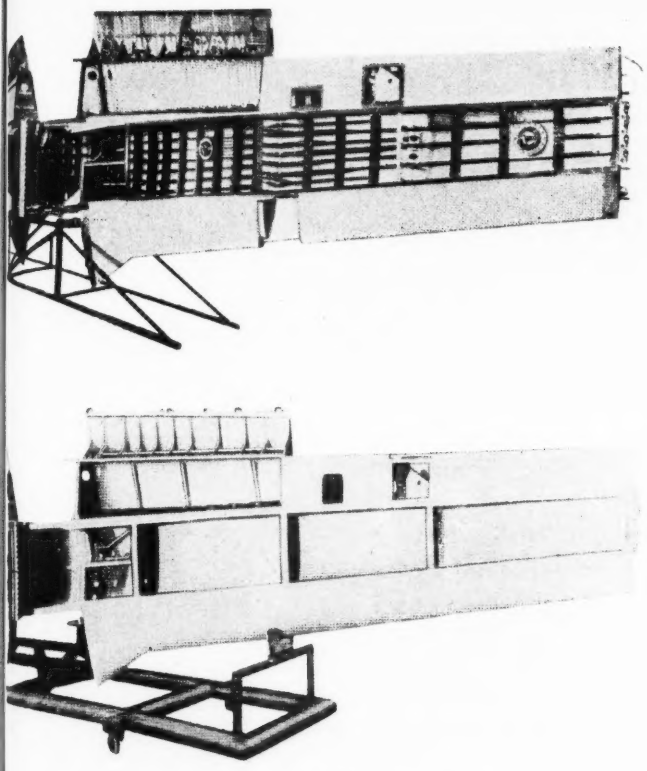


Fig. 13. *(upper)* Lockheed F-80 aluminium alloy wing panel: *(lower)* F.80C magnesium wing panel.

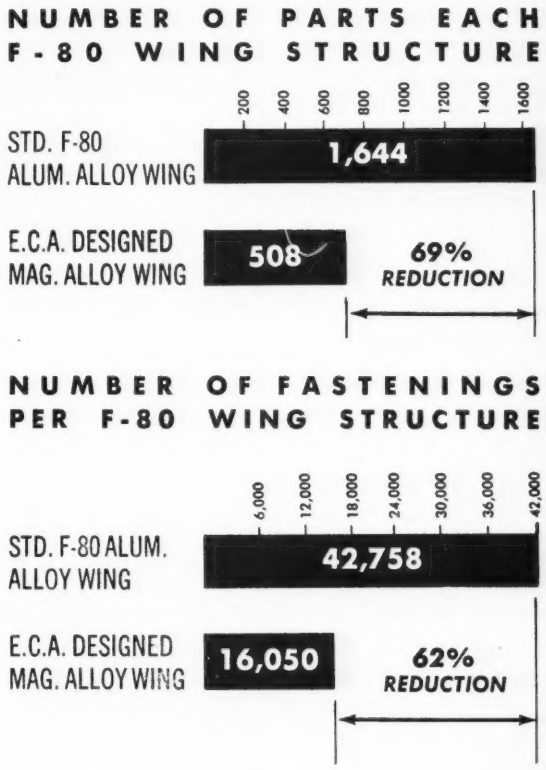


Fig. 14. Numbers of parts and fastenings for each F-80 wing structure in aluminium and magnesium alloy.

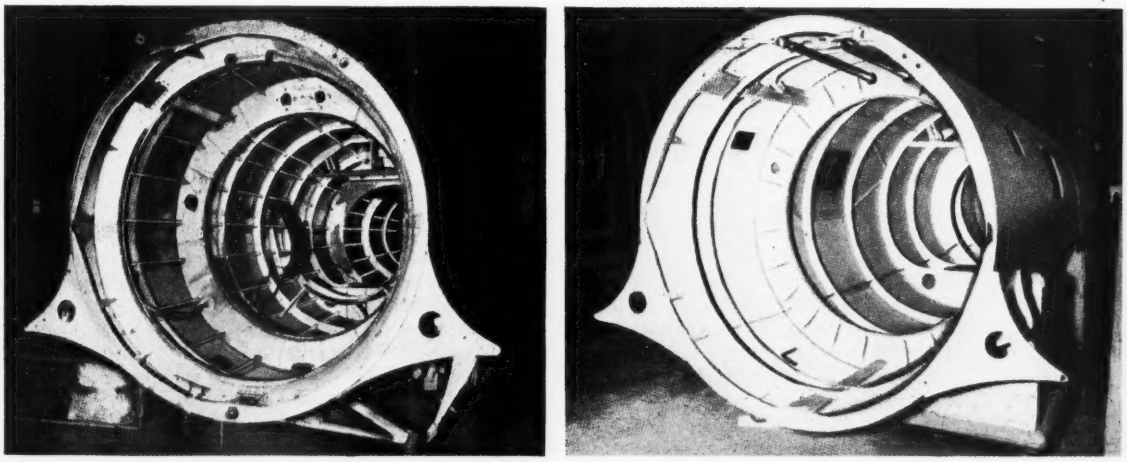


Fig. 15. F-80 fuselage: comparative aft-sections in aluminium and magnesium.

(The Author is indebted to Brooks and Perkins, Inc., of Detroit, for the use of Figs. 1, 4, 5, 9, 11 and 12/15, taken from various issues of their "Magazine of Magnesium", and to the Institute of Metals for the loan of blocks for Figs. 2 and 3.)

SESSION IV

RECENT ADVANCES IN THE APPLICATION OF RESISTANCE WELDING TO AIRFRAME CONSTRUCTION

by N. K. GARDNER, B.Sc.(Eng.), A.F.R.Ae.S.

In October, 1950, *Mr. Gardner joined the staff of Handley Page, Limited, where he is now a senior technical assistant. In* 1955 *he visited a number of aircraft factories in the United States and in France to examine their spot welding methods.*

Prior to 1950, *Mr. Gardner served in the Structures Department, R.A.E., and in the Experimental Engineering Department of Westland Aircraft, Limited. He also attended the Aircraft Design Course of the College of Aeronautics.*

Mr. Gardner.

DURING the past decade, the aircraft industry has seen a steady but remarkable increase in the use of resistance welding. This is not to say that any spectacular scientific advance has been made. What has happened has been a growth on the one hand in the quality of resistance welding equipment and, on the other hand, of the aircraft industry's appreciation of its uses. Further, perhaps more rapid growth, can be expected in the next few years.

In the aircraft industry, maturity of attitude to resistance welding has, in general, yet to be reached. The trend away from the exclusively riveted construction has taken different directions in different companies. In some firms, widespread use has been made of metal-to-metal adhesives; in others, there has been intensive development of integral construction; and in others the accent has been on spot welding. The initial tendency has been for each organisation to develop its own speciality to the exclusion of other methods. Signs of a reversal of this trend are now becoming evident. For one example, the Glenn L. Martin Company, perhaps the foremost exponents of adhesive bonding, are now using structural spot welding to an increasing extent. For another, the Douglas Aircraft Company, who make great use of integral construction and of automatic riveting machines, are actively considering extending their use of spot welding to primary structures. Examples could, of course, be quoted on the other side of those who have exaggerated the usefulness of spot welding and are now turning to adhesives in applications where they are more suitable.

These changes in production methods have followed or accompanied related changes in organisation. The aircraft industry of the past contained two separate organisations. One was led by men with 'know-how' rather than theoretical knowledge, the other by qualified designers often lacking in up-to-date knowledge of production methods. Now there is a third group, led by men whose experience and training earn them the respect of the other two. These are the production engineers. In their hands lies the future of resistance welding as of much else.

Great advances in the reliability of resistance welding have preceded its present use in primary structure by, for example, Boeing, Grumman, Handley Page and S.N.C.A.S.E. Rigid process control has been the essential factor in these advances. The growing

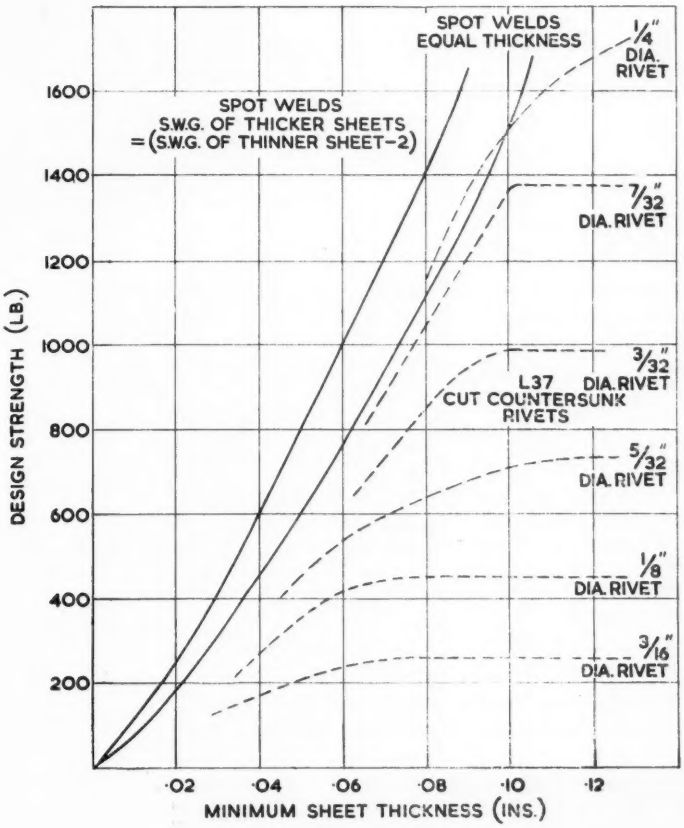


Fig. 1.

acceptance of statistical methods of quality control and of sampling inspection has, however, enabled success or failure to be economically assessed. In light alloy spot welding, improved radiographic techniques have provided the final check.

The ultimate test of reliability is obtained only by service experience. Here, encouraging evidence is becoming available. Boeing C97 and KC97 aircraft, for example, were reported in 1955 to have completed over 18,000 flying hours without cracking or failure of any spotweld. About 600 of these aircraft were built, each containing over 90,000 spot welds which included pressure cabin lap joints. Larger numbers of spot welds per aircraft are now used: the Boeing KC-135 (military forerunner of the 707) using 500,000 and the Grumman F-8F containing, according to Farrell (5) 1,500,000 spot welds.

In future high speed aircraft (Mach. No. 2.5 and above) resistance welding seems likely to find increasing favour. Here adhesives drop out of the field, while the weld is no more affected by environment than is the parent metal. The new airframe materials such as titanium alloys, stainless steels and the nickel alloys appear as a whole to be more readily and more efficiently weldable than are the present aluminium alloys.

1. Examples of the use of Spot and Seam Welding

The most common use of spot welding in airframes is for joining stiffeners to sheet. To various extents, this has been done on a number of aircraft. Caravelle, Comet, Herald, Stratocruiser and Victor are some examples. Drawn section stiffeners have commonly been used, but extruded and machined stiffeners are also used, even where fairly large thickness differences are involved.

Fuel tanks, both fixed and droppable, have been another favourite. Spot and seam welding, sometimes

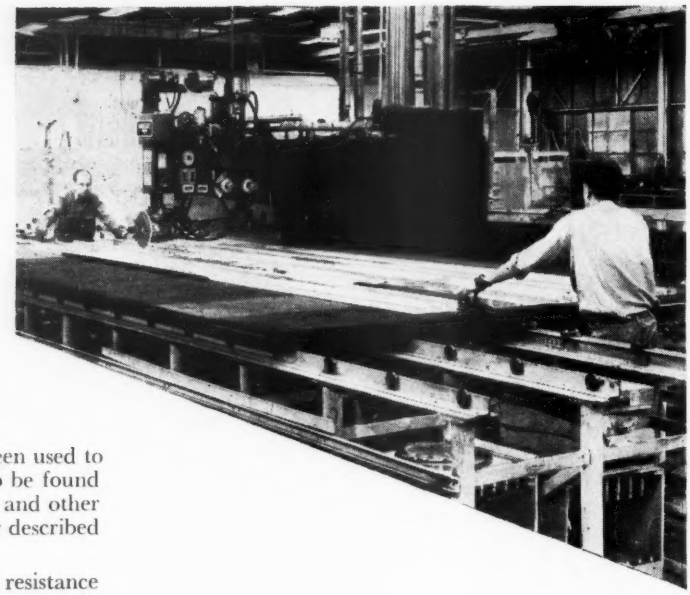


Fig. 2. Roll spot welding a Boeing fuselage panel lap joint.

in conjunction with fusion welding, have been used to simplify sealing problems. Examples are to be found in the Cougar, Hastings, Scorpion, Wyvern and other aircraft. (The Cougar application is further described below).

De-icing ducts have often been made by resistance welding, especially where the temperatures involved preclude the use of adhesives.

The joining of webs to booms by spot welding has been limited by the thickness difference which can be accommodated. Floor beams and ribs have been made in this way and it is to be expected that "distributed" flange spars will also use spot welding in some cases.

The two examples shown in Figs. 4 and 5 are not typical, but illustrate the possibilities of the method.

In the Cougar leading edge tanks (Fig. 4) Grumman have found the advantage of spot and seam welding to outweigh the accessibility difficulties involved. No weight is wasted by the use of sealants. The accessibility problems arising from the thinness of the wing and from the 51° sweepback angle are very severe. Grumman have solved these problems by special modifications to existing welding machines and by very ingenious welding jigs. Nearly all the welding is done single-handed and the cost saving over alternative methods must be considerable. The equipment used is described in detail elsewhere (1).

Fig. 3. Spot welding Victor air intake ducts at Handley Page, Ltd.

Boeing's "special purpose" lap joint (Fig. 5) is another very advanced application. Here the design aspects are of greatest interest. Static and fatigue strengths have been amply covered by tests, the validity of which are borne out by service experience. The process control methods underlying this achievement has been described by Gain (2).

2. Resistance Welding at the Design Stage

A good deal of knowledge and experience is now available to indicate when resistance welding is a suitable method of joining and when it is not. This knowledge cannot be condensed into a set of rules: each application must be considered separately and the relative merits of the alternative methods impartially assessed. Table I, therefore, should not be taken as anything but an indication of the factors which should be weighed.

The greatest advances are made when these decisions are taken by the designer and the production engineer working together at the project stage. The development work necessary to confirm these decisions and to obtain more precise design data is initiated at this stage.

Some examples of available design data are given in Appendix I.

The difficulties at this vital stage are in overcoming

EXAMPLES OF STRUCTURAL SPOT WELDING.

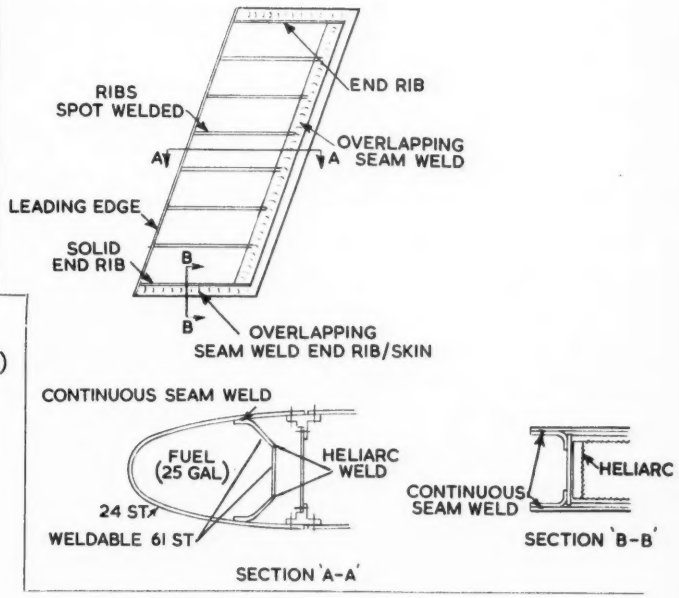
1. GRUMMAN F9F-8 COUGAR.

INTEGRAL LEADING EDGE WING FUEL TANK.

NOTES: NO SEALANT USED.

TOTAL WELDING TIME – 14 HOURS.

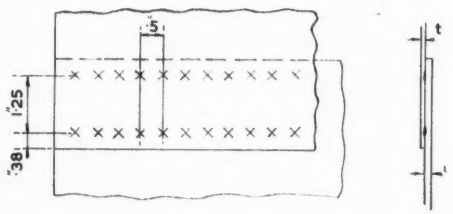
Fig. 4 *(right)*.



EXAMPLES OF STRUCTURAL SPOT WELDING.

2. BOEING C97 AND KC97 (STRATOCRUISER AND STRATOTANKER.)

PRESSURE CABIN LAP JOINTS.



MAT'L : 24-S

THICKNESS t – 18 S.W.G. – 15 S.W.G.

JOINT EFFICIENCY – 83·5%

MINIMUM REQUIRED FAILING STRESS 50,000 P.S.I.

ACTUAL SKIN STRESS AT WORKING PRESSURE 10,800 P.S.I.

Fig. 5 *(left)*

Table I. FACTORS AFFECTING CHOICE OF SPOT WELDING

1. Design Factors.

FACTOR	SPOT AND SEAM WELDING	ALTERNATIVES	
		RIVETING	ADHESIVE BONDING
Strength Static	80% joint efficiency in dural readily attained above 22 swg. (Ref. 10)	Flush riveting usually inferior	Inferior above 16swg Preferred below 20swg
Fatigue	Usually limited by other attachments (S.C.F. 2-3). (Ref. 11)	No advantage	Possible advantage only when unstressed
Finish	.001″ indentation with suitable electrodes. Quilting likely below 26 swg	Flush riveting tends to deteriorate in service	Superior in all thicknesses
Environment Heat, Corrosion, etc.	Unaffected in relation to parent metal Unaffected in relation to parent metal, excepting magnesium alloys	Electrolytic action not uncommon	Not above 200°C. May be sensitive
Sealing	Leakproof joints by : (a) seam welding ; (b) spot welding through sealant ; (c) spot welding plus minimum sealant.	Elaborate precautions required	No problem

2. Production Considerations.

FACTOR	SPOT AND SEAM WELDING	ALTERNATIVES	
		RIVETING	ADHESIVE BONDING
Accessibility Requirements	Access to both sides essential	One side sufficient (at expense of strength)	One side sufficient
	Minimum width of flat wedge distance required	No advantage	Probable advantage in thin gauges
Mobility	Immobile. Portable sub-assemblies only	Very mobile	No advantage
Size Limitations	Throat depth. Bath size (exceptional cases only)	No limit	Plant limitations
Thickness Limits	(i) Governed by machine capacity (upper and lower limits) ; (ii) no more than four thicknesses as a rule ; (iii) thickness difference limited (2 - 3 even gauges)	No limit but dimpling required in thin gauges	No limit but fit critical in heavy gauges
Material Limitations	Limited to materials forming sound alloys	No limit	No limit
Economic Considerations	Avoid using in isolated groups Batch production preferred		

3. Control and Inspection.

FACTOR	SPOT AND SEAM WELDING	ALTERNATIVES	
		RIVETING	ADHESIVE BONDING
Process Control	Effective. Serious loss of strength of entire assembly extremely remote. Control of fit of parts vital		Loss of entire assembly a possible hazard
Quality Control	Control by normal statistical methods applicable (Ref. 19). Controls process but does not cover faults due to lack of fit		Sampling methods inapplicable except by destruction of selected assemblies
Inspection	Radiography effective for aluminium alloys. No effective method for steels and titanium (Refs. 21 and 22)		No fully effective method available

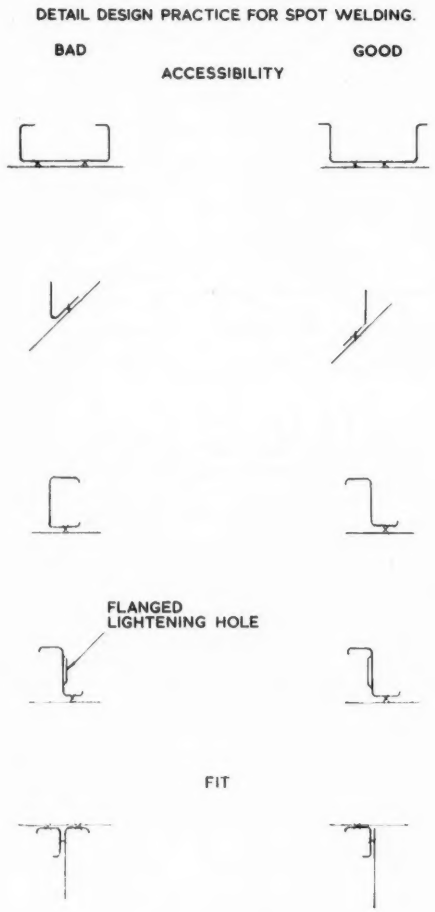


Fig 6.

natural prejudice (either against or for spot welding) and in distinguishing between what is possible and what is desirable.

The production engineer must again exert his influence at the detail design stage. The limitations of the spot welding process in general are now well known, but exceptional cases may still have to be dealt with by test. To these must be added the limitations of the equipment to be used. Questions of accessibility and fit are largely a matter of common sense, but mistakes frequently occur. Fig. 6 shows how these can be presented to the draughtsman in sketch form. It is noteworthy that in most cases no loss of structural efficiency is involved in correcting a design to good spot welding practice.

3. Welding Equipment

The principal advance in spot welding equipment has been improvement of consistency and reliability. Modern welding machines are capable of producing thirty consecutive welds with a coefficient of variation of strength less than 4%. Used over periods of several months, coefficients of variation of 7-8% can be obtained. A consistency at least the equal of that of riveting is thus available. If the control procedures described below are followed, there is no reason why such consistency should not apply in production over indefinite periods.

Output Characteristics

A number of fundamentally different types of spot welding machine have emerged. The advance has been one of progressive refinement and progressive complication, the most modern types controlling up to ten variables by use of over one hundred electronic valves. The more refined examples of each type have their place in airframe spot welding; and indeed their advantages, if simplicity is included as an advantage. A more detailed account of the types of machine available is given in ref. 15.

To appreciate the relative advantages of the available output waveforms, a brief examination of the process of formation of a spot weld is first necessary.

The function of the spot welding machine is to supply energy to a local volume of metal so rapidly that local fusion occurs without undue heat loss into surrounding material. The rapidity of supply required will obviously depend in part upon the thermal conductivity of the material. From Table II it is obvious that a much more rapid supply of energy is required for aluminium alloys than for stainless steels and titanium. Heat generated at the outer surfaces of the sheets (arising from contact resistance) is conducted away through the water-cooled electrodes. If the rate of current rise is too great in relation to surface resistance, this electrode cooling is unable to prevent surface melting.

Clearly it would appear desirable to control the rate of current rise. The slope control modification to the simple AC waveform (Fig. 7.1) has this object. Direct control over the number of cycles to peak current is also a feature of the three-phase type of machine. Direct control is not available on stored energy machines, but adjustment is possible. The stored energy machine with its rapid current rise and slower decays is, however, very well suited to the spot welding of aluminium alloys.

Electrode pressure also affects surface resistance and the higher "precompression" adopted in some machines is designed to eliminate resistance "high-spots".

If cooling is allowed to take place too rapidly, the thermal stresses set up can lead to internal cracking. This can be overcome in two ways:

(i) forging pressure can be applied to neutralise these stresses. This is effective only if applied

Table II. Physical Properties Relative to Spot Welding.

	Aluminium Alloy DTD 610	*Stainless Steel* 18 - 8	*Titanium*
Thermal Conductivity CGS units (100°C.)	0.32	0.037	0.038
Electrical Resistivity (20°C.) Microhm/cm³	5.7	70	55.4
Melting Point °C.	540	1400	1660

while the fused zone remains plastic, and its timing is very critical. The rate of application of the forging pressure must also be sufficiently rapid to cause the electrode to follow the rapidly shrinking weld;

(ii) the rate of cooling can itself be reduced by the controlled application of "current decay" during the cooling period, as in the three-phase type of machine (Fig. 7.3), or of "taper" in the single-phase machine (Fig. 7.1).

To sum up, the stored energy machine is a specialist machine for light alloy welding. Although the single-phase machine with the refinements described can also be used for light alloys it is, in fact, not very much used for this purpose in the aircraft industry. The popularity of the three-phase machine, which is the most versatile of the three types, is growing, and for airframe work this type is now being used more than any other. With versatility goes complexity and much more development work is required to make the best use of this machine than is required for the simpler types.

Configuration

Three machine configurations are available:

(i) the press type, in which the upper electrode moves in a fixed guide (usually directly connected to the piston of a pneumatic jack);

(ii) the rocker arm type, in which the upper electrode is fixed to a pivoted upper arm;

(iii) the roller type, in which electrodes are replaced by wheels, one of which is driven.

Of these the press type is most commonly used and is the most versatile. Its advantage over the other two lies in the low inertia of moving parts, making rapid "follow up" of pressure easier to achieve. The rocker arm type has certain accessibility advantages, the region of the upper electrode being less encumbered and the maximum clearance between electrodes being greater.

The roller machine has production advantages where long straight runs are required on unobstructed assemblies, and for seam welding (i.e., making overlapping spot welds). Inertia and secondary circuit impedance tend to be high, so that it is heavier and more powerful than the equivalent press-type machine (a 200 K.V.A. roller machine being the equivalent of a 100 K.V.A. press-type machine). Delays for electrode cleaning, necessary after every 30 - 40 welds on press-type machines, are eliminated. Again, this alignment of electrodes after changing is more critical and more difficult than on press-type machines. Accessibility is of course much poorer than for the other types. In particular the existence of stiffeners, etc., running at right angles across the line of welds will limit its use. It is at the same time the least versatile and potentially the most productive of the three types.

4. Control and Inspection

It has been demonstrated that welding machines have been developed to give entirely adequate consistency under laboratory conditions. To maintain acceptable consistency in production, however, presents another set of problems. Failure to appreciate the magnitude of these problems has led to some disheartening experiences in the past and explains the mistrust of welding still current in some quarters.

That considerable advances in this connection have taken place is evident from the current applications described earlier in this Paper.

A brief examination of Table III will indicate that spot welding cannot be introduced into the production system of a new aircraft in a few months. Only by starting at the earliest stage in the design of the aircraft can success be ensured. If a sufficient time for development work is allowed, the introduction of spot welding can be synchronised with the progress of the new aircraft.

The details of the techniques employed have been

described exhaustively elsewhere (refs. 17 - 23). In the following it is proposed to deal only with the underlying principles. The principles involved are of course no different from the principles of control of any process. A statement of these principles, however, seems timely, in light of the growing importance and complexity of the subject.

Three methods have been developed to maintain quality :

(i) Process Control ;
(ii) Quality Control ;
(iii) Inspection.

These can be regarded as three screens through which the product passes in turn. The second and third screens, if used, exist to detect faults remaining due to shortcomings in their precursors.

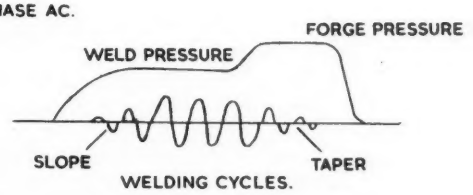
The terms Process Control and Quality Control are frequently used indiscriminately ; they represent distinct ideas.

By Process Control is meant the control of all variables which affect the relevant properties of the product. This implies keeping each variable within specified limits. To be effective without being wasteful, such limits should be based upon tests by which

Figs. 7.1, 7.2, 7.3.

TYPES OF WELDING CYCLES FOR SPOT WELDING.

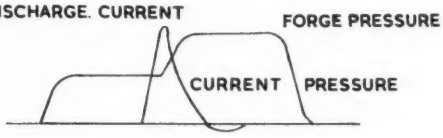
1. SINGLE PHASE AC.



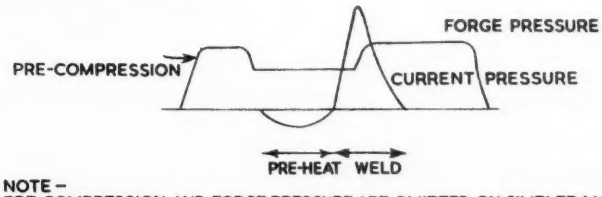
NOTE –
SLOPE, TAPER, FORGE PRESSURE } ARE REFINEMENTS OMITTED IN SIMPLER MACHINES

2. STORED ENERGY.

a) CONDENSER DISCHARGE. CURRENT

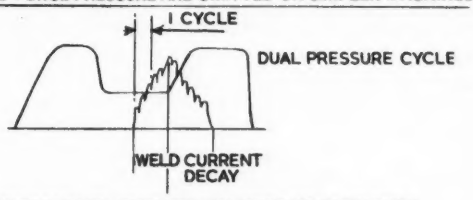


b) ELECTROMAGNETIC.



NOTE –
PRE-COMPRESSION AND FORGE PRESSURE ARE OMITTED ON SIMPLER MACHINES

3. THREE PHASE.



NOTES– CURRENT DECAY MAY BE OMITTED ON SIMPLER MACHINES
MULTI-IMPULSE CURRENT CYCLE ALSO POSSIBLE
THUS–

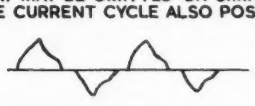


Table III

THE INTRODUCTION OF SPOT WELDING ON A NEW DESIGN.

1. Design.

A *Project Design Stage*	B *Overall and detail design stage*	C *Prototype Manufacture*	D *Immediately Prior to Production*
Decisions where to use spot welding (see Table 1)	Check on design to ensure welding can be practicable and economical. Strength calculations on basis of provisional figures.	Drawings modified where necessary in light of production experience.	Inspection classification added to drawings. Revised strength data available for check stressing (from 3D below).

2. Process Development and Control.

A *Project Design Stage*	B *Overall and Detail Design Stage*	C *Prototype Manufacture*	D *Prior to Production*	E *Production*
Choice, Purchase, Installation and Calibration of Welding Machines.				
Determination of Optimum Settings.		Monitoring of output waveforms.		
Evaluation of Process Variables.		Records kept of all process variables.	Final approval of machine settings (from 3D below) Settings of limits to process variables.	Inspection to verify approved settings are used and the variables are within limits.
Manufacturing Exercises.				
			Maintenance schedules set up.	Routine machine maintenance.

3. Quality Control

A *Project Design Stage*	B *Overall and Detail Design Stage*	C *Prototype Manufacture*	D *Prior to Production*	E *Production*
Consistency panel tests, preliminary Design data and Control Limits determined.		Full quality control using provisional control limits.	Analysis of control charts from (C). Revision of design data. Revision of control limits. Correlation of faults with process control.	Full quality control using revised control limits.

Table III (continued)

A *Project Design Stage*	B *Overall and Detail Design Stage*	C *Prototype Manufacture*	D *Prior to Production*	E *Production*
	Simulated service tests on assemblies with faulty welds.			
	Development of radiographic technique.	All assemblies checked for fit prior to welding.		
		100% radiographic inspection of all structural welding.	Analysis of 4C in conjunction with 2D and 3D. Definition of what is to be termed a defective weld. Acceptance limits for assemblies defined.	Sampling inspection graded according to structural importance.

the effect of each variable upon the product is determined.

Quality Control, on the other hand, involves periodic measurement of those properties of the product which are of interest to the customer (or the designer). Corrective action is taken if these measurements fall outside prescribed limits, termed "control limits". The most important feature of the control limits is that they are *not* related to the customer's (or the designer's) requirements. On the contrary, they represent what can reasonably be expected of the process when working normally. The key word here is "normally". Failure to remain within these limits is taken to indicate abnormality and hence to warrant corrective action. The idea of control limits is a statistical concept; they are, in fact, calculated by statistical analysis of trial runs or of past experience.

There is sufficient agreement as to the meaning of the term Inspection to make definition unnecessary. It differs from the other two measures in that it is concerned with the product rather than the process. The decision to accept or reject the product, which is the function of inspection, must depend upon the customer's (or designer's) requirements in the particular case concerned, and not upon whether the process is functioning correctly.

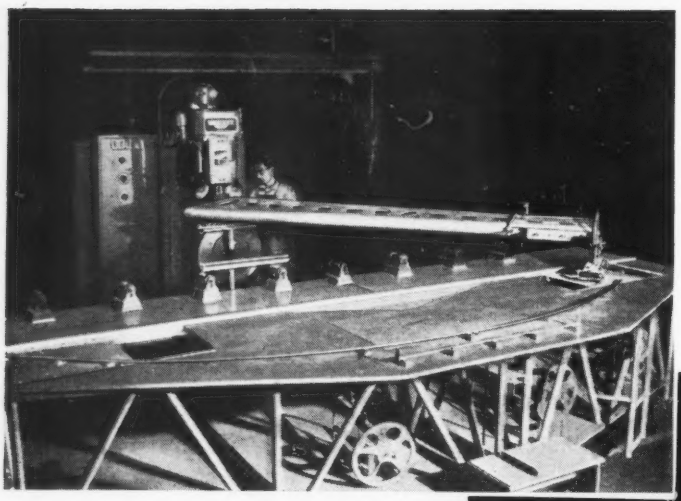
A further word by way of definition is necessary in relation to design data. The logical approach is to make the designer aware of the capabilities of the process when functioning normally. The illogical (but common) approach is for the designer to state what he requires of the process. The designer may in a given application require more or less of the process than it is capable. If he requires less, this should not influence the conduct of the process but should only affect the inspection decision (and then only in abnormal cases). If he requires more, then he must either change his design or use another process.

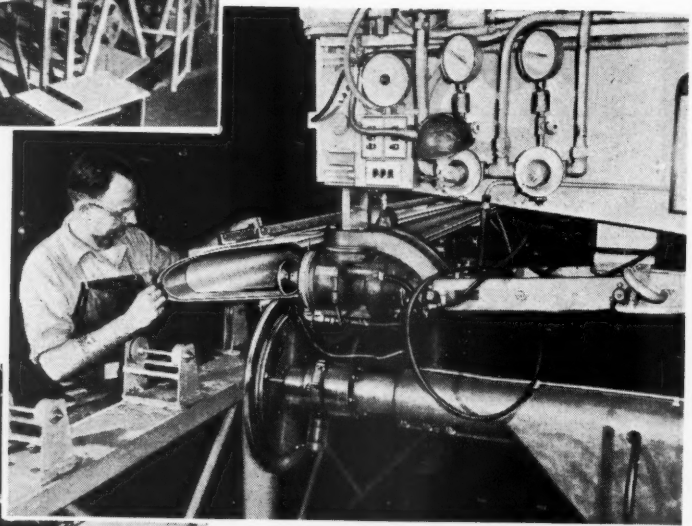
Information regarding a process is usually transmitted to the designer in the form of "design allowables" (to use the American phrase). These are calculated from the same data and in the same manner as are the control limits, namely by statistical analysis of the properties of the product when the process is functioning normally. A further factor enters into this calculation: the risk that in any instance the product will fail to achieve the design allowable (in the case of a spot weld this is the risk of the weld failing at or below the design strength). The choice of this risk is the designer's responsibility. He will be aware that the smaller the required risk, the lower will be the design allowable.

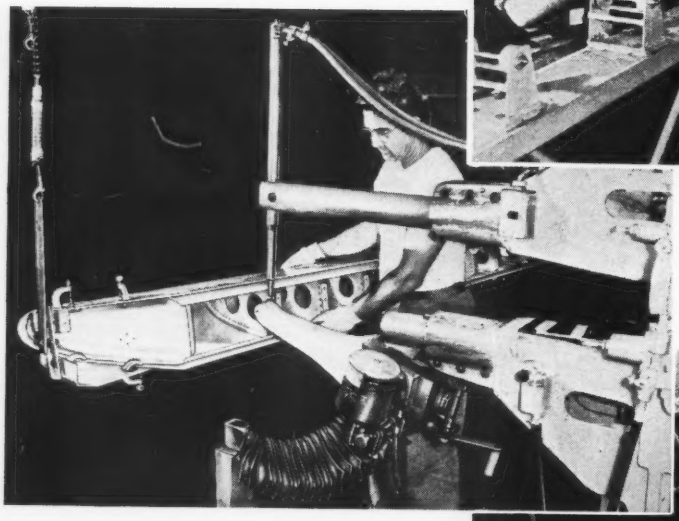
A word, now, about the relations between these three measures.

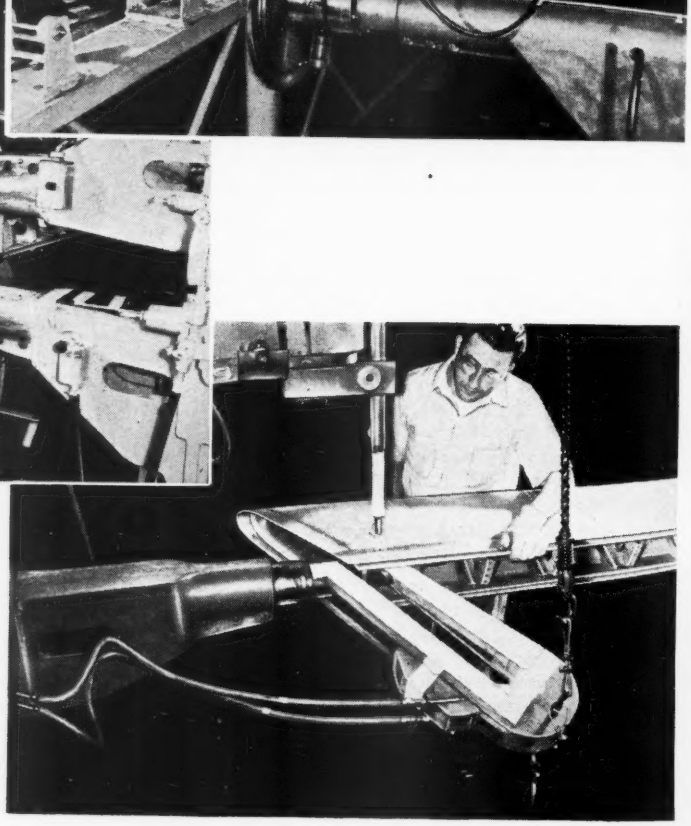
Process Control is in all senses the primary one. As its achievement approaches perfection, the need for the other two measures tends to vanish. That more can be gained by developing this aspect than the other two is obvious — it is just another way of saying that prevention is better than cure. The elimination of human skill from the process is almost essential to effective control. The art of mechanical control has made and is making rapid advances, with the growing use of self-correcting mechanisms.

Between these extremes Quality Control is used to measure the success of the Process Control and to detect its failures. It must be rapid and direct: it should be cheap and simple. Its usefulness is greatly extended if it forms a permanent record which is regularly analysed. Frequently it enables adverse









Figs. 8. - 11. These photographs show special equipment used for Grumman leading edge tanks.

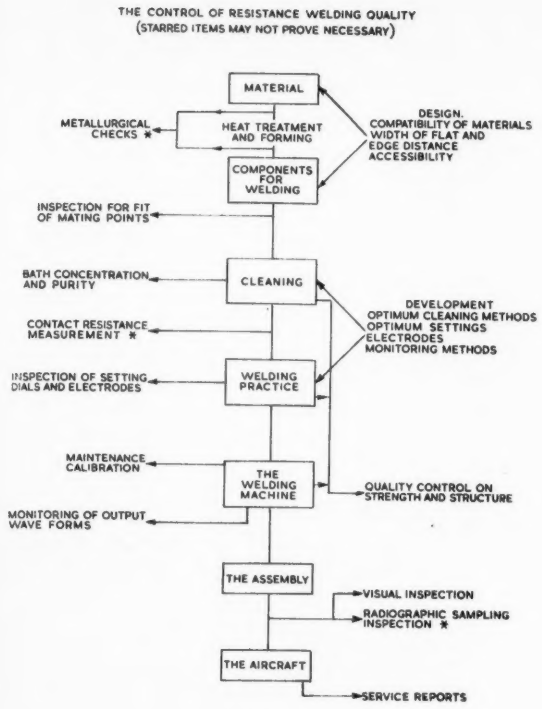

THE CONTROL OF RESISTANCE WELDING QUALITY
(STARRED ITEMS MAY NOT PROVE NECESSARY)
MATERIAL
METALLURGICAL CHECKS *
HEAT TREATMENT AND FORMING
DESIGN. COMPATIBILITY OF MATERIALS WIDTH OF FLAT AND EDGE DISTANCE ACCESSIBILITY
COMPONENTS FOR WELDING
INSPECTION FOR FIT OF MATING POINTS
BATH CONCENTRATION AND PURITY
CLEANING
DEVELOPMENT OPTIMUM CLEANING METHODS OPTIMUM SETTINGS ELECTRODES MONITORING METHODS
CONTACT RESISTANCE MEASUREMENT *
INSPECTION OF SETTING DIALS AND ELECTRODES
WELDING PRACTICE
MAINTENANCE CALIBRATION
THE WELDING MACHINE
QUALITY CONTROL ON STRENGTH AND STRUCTURE
MONITORING OF OUTPUT WAVE FORMS
THE ASSEMBLY
VISUAL INSPECTION
RADIOGRAPHIC SAMPLING INSPECTION *
THE AIRCRAFT
SERVICE REPORTS

Fig. 12.

trends to be detected before they become serious : that certainly is its object.

Where the adverse trend may be too rapid for the Quality Control system or where loopholes exist, Inspection is necessary. It can seldom be completely eliminated, although where quality can be measured rapidly and non-destructively it may need no other source of information than that provided by the Quality Control system.

The control and inspection measures used for spot welding are summarised in Fig. 12.

5. Consistency in Production

The records now available relating to the production of the Victor bomber illustrate the foregoing.

The control and inspection techniques employed are described in ref. 19 and 22.

During the production of two prototypes and the test components, 100% radiographic inspection was applied to the majority of spot welded assemblies.

Results were — (approximately) :

Welds examined	300,000
Proportion defective	2—3%

The principal cause of defects was found to be lack of fit of mating parts.

Of the 2—3% defective, it is estimated that none fell below 50% of design strength.

Tests on the main wing construction showed that the loss of nine adjacent welds in the most adverse pattern led to a loss of structural strength of only 12%. Partially defective welds produced much smaller losses (the existence of nine welds 30% of normal area giving reduction of 5%).

These results were sufficiently encouraging to justify a relaxation of radiography and an increase in the number of spot welds per aircraft.

All welded components were classified according to their structural importance and a graded sampling scheme was introduced. Sampling was not of assemblies, but of welds within assemblies.

Analyis of records after a considerable period in production gave the following results :

Total number of welds	7,230,000
Number inspected by radiography ...	1,800,000
Number defective	46,000
	(=2.5% approx.)

On the basis of these results, further reduction of radiographic inspection has been made by reclassifying less important assemblies.

The design strengths used were approximately 40% above the United States MIL W6860 specification.

6. Productivity and Costs

Advances in productivity have taken place more rapidly in the United States than elsewhere. In many cases, United States aircraft manufacturers (notably Glenn L. Martin) have adopted spot welding in preference to riveting purely on the grounds of cost reduction.

A few examples will show the order of output that can be achieved :

Boeing output figures (2) follow :

Application : Fuselage skin/skin and skin/stringer joints 174,000 lb. A.U.W. Transport.

No. of welding machines used : eight (three-shift five-day week).

No. of welds per aircraft : 90,000.

Output : 23 aircraft per month = 500 welds/machine/hour = 8.5 welds/minute.

(NOTE : Since the welding machines were operated at 40 - 70 welds/minute the percentage utilisation was 5% - 8%.)

Estimated cost per weld : 2d.

Day and Night Aircraft (3) give the following estimated data :-

Application : Integral tip tanks for fighter aircraft diameter = 42", length 40' approximately,

Spot weld output : 640 welds/machine/hour.

Seam weld output : 20 tanks per week at estimated 50' per tank using two seamwelders.

A similar spot weld output rate has been estimated by Grumman (1).

Liberty Products Corp., Farmingdale, New York, quote much higher output figures and give in the

RIVETED			SPOT WELDED		
Operation	*No. off*	*Time mins.*	*Operation*	*No. off*	*Time mins.*
Drill and Deburr	4,076	787	Drill and Deburr	432	83
Dimple and Rivet	4,076	271	Dimple and Rivet	432	30
			Clearing		7
			Roll-spot Welding		61
	TOTAL : 1,058			TOTAL : 181	

Table above a comparison between riveting and spot welding of 20 s.w.g. elevator panels :

Lower outputs and higher costs (the factor being perhaps two in each case) probably obtain in this country. This can be partly explained by the smaller numbers of machine sets required. The attention paid to jigs and fixtures (1) (2) in the United States has undoubtedly had a beneficial effect. If more than one or two men are employed per welding machine, the jigging is regarded as inadequate.

Some ways in which productivity can be increased are :-

1. restriction of welding to cases where it is best suited for production ;
2. Attention to detail design to give adequate accessibility ;
3. avoidance of use of welds in small groups on large assemblies ;
4. planning to give long runs on each assembly rather than producing one aircraft set at a time ;
5. work study to reduce idle time ;
6. process control (which is cheap) made as rigorous as possible, leading to reduction or elimination of radiography (which is expensive).

The greater familiarity with spot welding in the United States has made operators more confident of its reliability than in this country. Very little radiography of spot welded assemblies is employed.

7. Flash-Butt Welding

Flash-butt welding of steels and of the lower grade aluminium alloys is not uncommon. In the aircraft industry, a typical application is the joining of fork ends to tubes for control circuits and other

HYPOTHETICAL SHOP LAYOUT SHOWING SEQUENCE OF OPERATIONS.

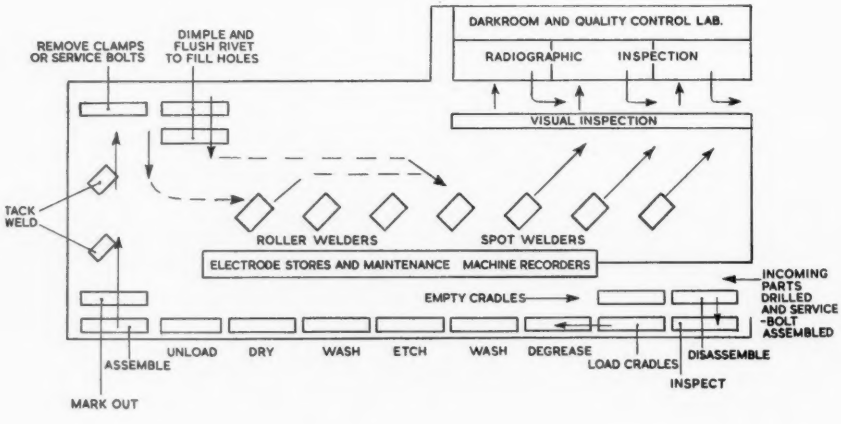


Fig. 13.

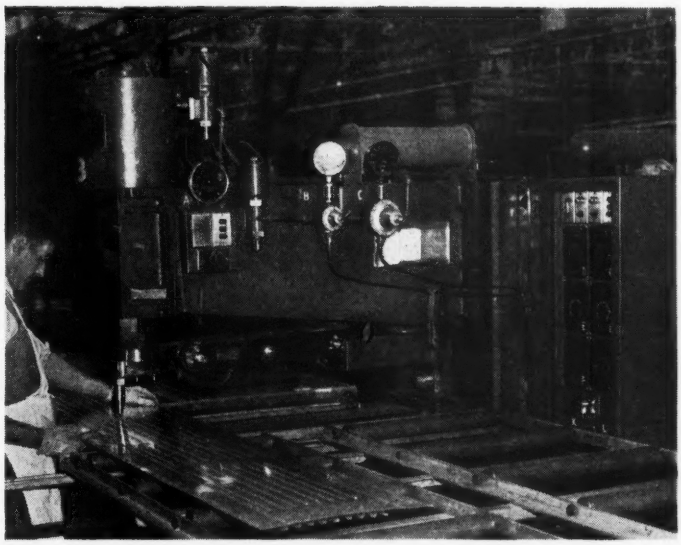


Fig. 14. Corrugation-reinforced panel for the Herald wing.

mechanisms. The weight saving is appreciable compared with riveting, since the plug end need not protrude more than a fraction of an inch within the tube.

It seems likely that this method can be applied to titanium without the use of inert gases, providing one of the few methods of achieving an efficient joint in titanium tubing.

Recently, it has been found possible to flash-butt weld 75ST to give a 90% joint efficiency. This could result in considerable weight-saving or reduction in machining time on present aircraft.

The present obstacle to the application of this method to large aluminium sections is the size and cost of the necessary welding machine; current densities of about 100,000 amps. per square inch (compared with 20,000 - 30,000 for steel) and upset pressures of about 50,000 p.s.i. will be required. A 500 K.V.A. machine, capable of welding up to two square inches of aluminium alloy, costs approximately £25,000.

8. Conclusions

Advances have been made in the application of resistance welding to airframe production, and advances remain to be made.

The necessary conditions lie more in the internal organisation of individual companies than in further technical advances. Where a body of professional production engineers exists and is enabled to devote sufficient energy to the outstanding problems, further advances are certain. Elsewhere, they are unlikely.

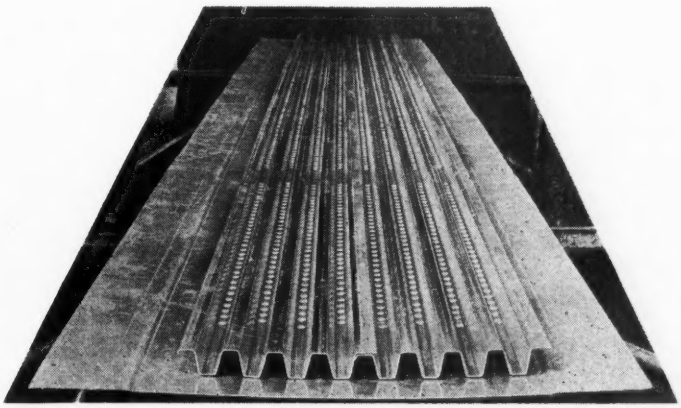


Fig. 15. Another view of the panel shown above.

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APPENDIX 1

DESIGN DATA

A great deal of design data is available (Refs. 7-14).
A brief and approximate summary is given below.

1. *Static Shear Strength*

Design Values lb./spot.

s.w.g.	*Aluminium Alloys*	*Stainless Steel* 18/8	*Titanium Commercially Pure and Alloyed*
		Ref. 9	
26	130*	270	800
22	355*	580	
18	700*	1,270	2,500
16	950*	1,900	3,700
14	1,200*	2,600	
10	3,200†	4,000	
8	3,900†		
	Applies to DTD 687; for DTD 610 and DTD 546 multiply by 0.9.	UTS 70,000 to 150,000 p.s.i.	Applies to Ti 130 Ti 160 Ti — 7% Mn Ti — 6Al 4V

* Ref 7. † Ref. 8.

(*concluded on page* 261)

CONTOUR ETCHING

by A. W. SHEPPARD

Mr. Sheppard served an indentured apprenticeship in the Engineering Shops and Engineering Design Office of John Samuel White & Company, Limited.

He joined Saunders-Roe, Limited, on the Design Staff in 1938, *later transferring to the Production Engineering Department on Jig and Tool Design. He became Chief Jig and Tool Draughtsman in May,* 1953, *and was appointed to his present position as Production Engineer in September,* 1955.

THE etching of metals by the application of chemicals is by no means new to industry ; for many years now, in pickling, descaling, and photogravuring, chemicals have been used to etch away unwanted metal.

A more recent example of etching by chemicals is in the electronics world, for the manufacture of strain gauges (Fig. 1).

Broadly speaking then, the process of chemical milling or contour etching which I shall describe is the latest step forward in this same field, but it permits the removal of more metal in less time. Its introduction resulted from difficulties encountered in forming sheet to the required contours after machining ; with contour etching it is now possible to form sheet to the necessary shape and then to etch or mill the geometric reliefs dictated by design requirements. Practice, however, has shown that the process has many other virtues and the chief of these can probably be summarised as follows :-

1. a considerable economy in machine tool requirements ;
2. a saving in weight which the designers have been quick to exploit ;
3. elimination of a large number of detail tools ;
4. simplified paperwork control of a job in that one process sheet, one job card, tool card, etc., is all that is necessary for what would otherwise be a component comprised of several separate items, each with its own paperwork.

Depths of a $\frac{1}{4}''$ are common in this country, although depths of more than $1''$ are possible at the present time.

Whilst the technique may differ between individual companies here, in America, and elsewhere, basically the process consists of four stages and, for the purpose of this Paper, I will outline the procedure followed by my Company, giving examples of the production specimens produced with, I hope, sufficient information for a comparison to be drawn between this new method and other means of manufacture.

Although etching by alkaline, acid and electrochemical means has been applied to aluminium alloys, magnesium, titanium, copper and steels, including stainless, in this Paper I shall deal primarily with the procedure employed for the etching of aluminium alloys, as it is in these materials that most of our more interesting components have been produced.

This Paper, then, will be divided into the following headings :-

1. Description of Process.
2. Application, Comparative Times, and the Weight Factor
3. Physical and Mechanical Effects.

1. Description of Process

This consists basically of four stages, as follows :-

(i) pre-treatment cleaning of material ;

(ii) application of resistance medium (known as 'masking') ;

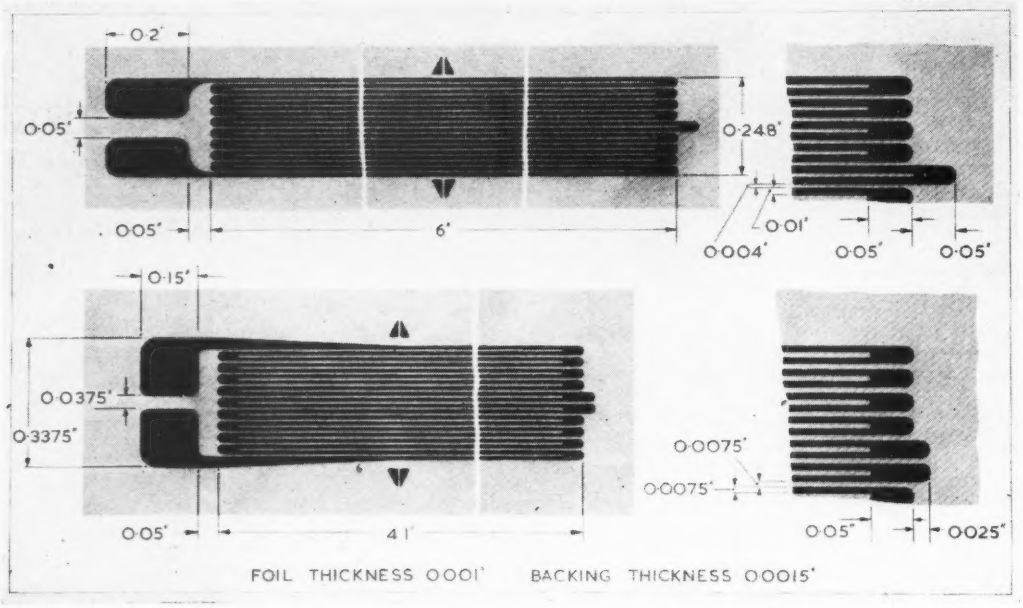


Fig. 1. Strain gauge which has been masked with a photo-sensitive resist and etched in ferric chloride at 65°F. for approximately 15 minutes.

(iii) etching ;
(iv) post-treatment — neutralising and cleaning.

(i) *Pre-treatment cleaning of material*

This entails degreasing and pickling to give a chemically clean surface which is also suitably receptive for the resist, and is carried out by degreasing in trichlorethylene vapour for 20 minutes, followed by pickling in a chromic-sulphuric acid solution for a further 20 minutes. After this, the component is water washed for 10 minutes in both cold and hot water.

(ii) *Application of resistant medium — ' masking '*

Prior to applying the resist, the component must first be covered on the surface to be worked with a strippable coating. over which is placed a stencil defining the contour of the area to be etched. A knife is then traced around the periphery of the stencil to cut the strippable coating which is peeled off in the areas where etching is not required. The component is next sprayed with a standard aircraft etch primer to ensure complete adhesion of the resist, after which it is stoved for 15 minutes to remove solvents.

The component is now ready for the application of the resist — a polyamide cured epoxy surface coating which is sufficiently flexible to allow gases produced during etching to escape. Examples of edges produced by badly formulated resists are shown in Figs. 2 and 3 ; Fig. 4 shows a good edge.

After spraying on the resist the item is stoved in an oven for 30 minutes at 120°C., or, alternatively, by infra-red lamps. (See Fig. 5 for curing times.)

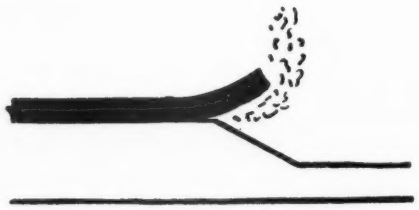


Fig. 2. Defective resistant coating being lifted off the surface of the sheet due to poor adhesion, or due to stiffness of resist resulting in flapping causing peeling.

Fig. 3. Resistant coating too stiff, causing gas trapping, and so inhibiting etching.

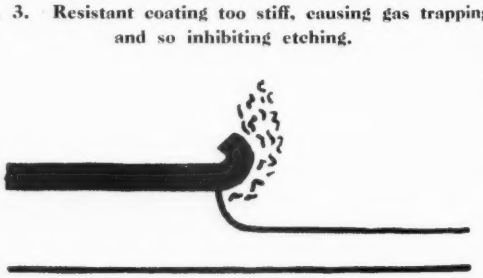


Fig. 4. Correctly formulated resist giving controlled radius at edge.

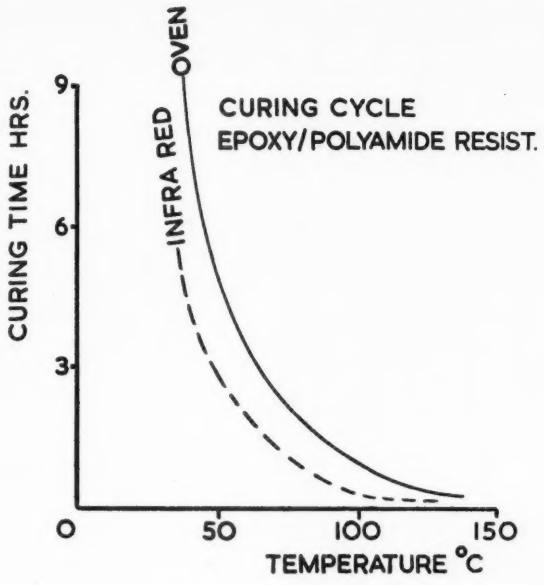


Fig. 5. Curing times.

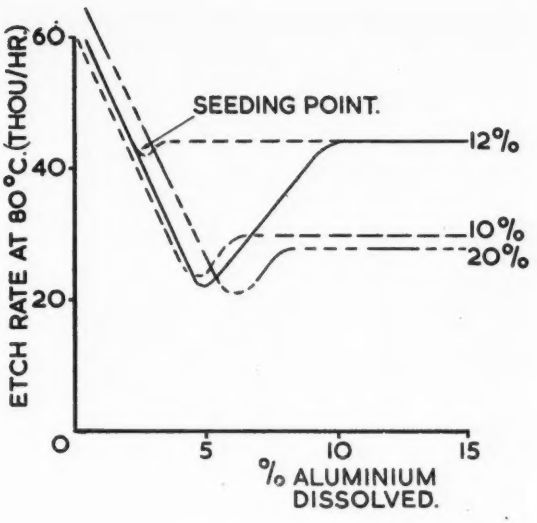


Fig 6. Etching.

Finally, the strippable coating is removed, thus exposing the areas to be etched.

(iii) *Etching*

Etching is carried out by placing the component in a hot alkaline solution for a specified time to remove the metal in the unmasked areas. The bath is a 12% sodium hydroxide solution modified by bringing the aluminium content of the solution to 2.5% and seeding with aluminium oxide, to give a constant etch rate of .045 per hour at a fixed temperature of 80°C. (see Fig. 6). The reaction between the sodium hydroxide and the aluminium may be represented by the following equation :-

$$2NaOH + 2Al + 2H_2O \rightarrow 2NaAlO_2 + 3H_2 \uparrow$$

Sod.Hydroxide, Aluminium, Water, Sod.Aluminate, Hydrogen

The sodium aluminate, which has a depressing effect on the etch rate, is converted to alumina which is precipitated and removed as a sludge by centrifuging — sodium hydroxide being regenerated, thus a constant etch rate is achieved. The hydrogen generated during the reaction should be removed by venting. The graph (Fig. 7) shows the behaviour of new etching solutions of various strengths in the unmodified condition, which emphasises the importance of temperature control and shows the etch rate.

It should be mentioned here that if stepped etching is required which necessitates progressive masking, provided the procedure outlined under the headings (ii) and (iii) is carried out right away, the pre-treatment described may be dispensed with.

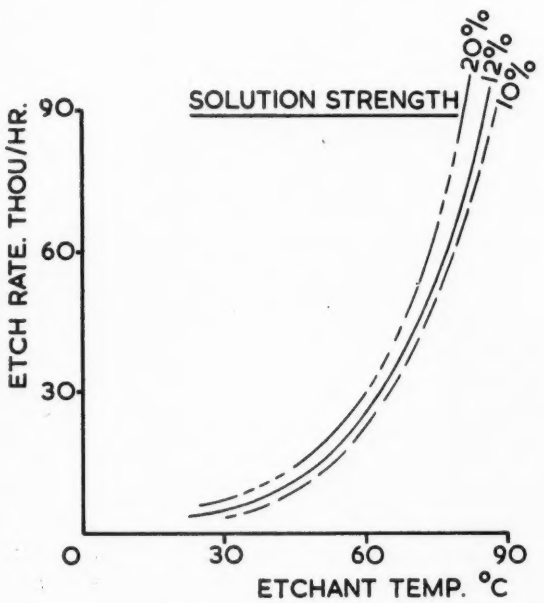


Fig. 7. Behaviour of new etching solutions of various strengths in the unmodified condition.

(iv) *Post-treatment — neutralising and cleaning*

This involves a cold water wash for five minutes, followed by immersion of the component in a cold 10% - 30% nitric acid solution for five minutes to remove the 'smuts' and neutralise. A further water wash, entailing a cold and hot rinse for 10 minutes, is followed by the final operation of removing the resistant coating by submerging the component in a suitable paint remover for 10 minutes.

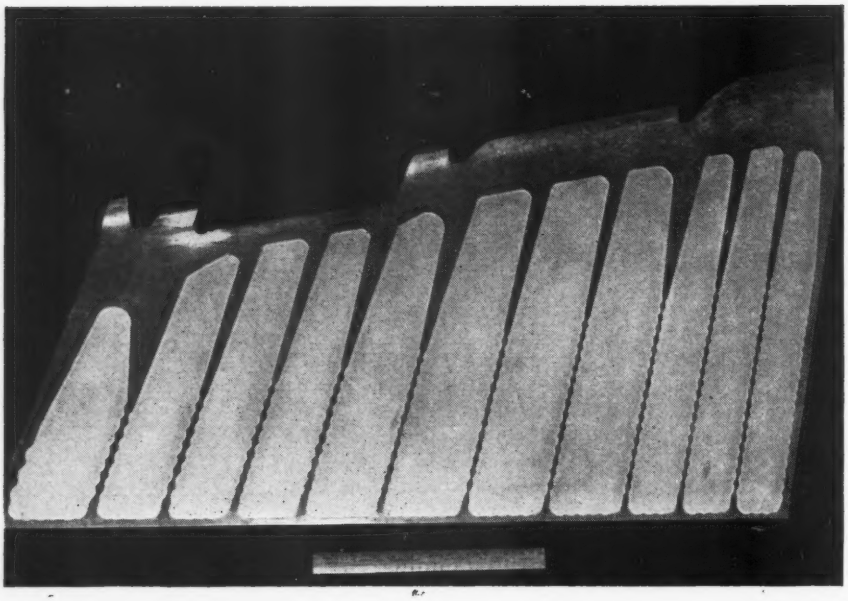


Fig. 8. Panel produced by contour etching in 4¼ hours, against 15 hours by normal machining methods.

The component should then be washed for five minutes, dried, and surface protected as for a machined item, i.e., anodised or lanoline coated.

The surface finish is inspected against master samples which have been approved by the Design and Inspection authorities, and these are in two grades :

Grade 1 — is the equivalent of the finish produced on an age-hardened plate and is free from blemishes ; this finish is only insisted on where the fatigue life is of paramount importance.

Grade 2—finish is similar to that obtained by etching plate in the solution treated condition and is the minimum standard which can be accepted where Grade 1 has not been specified on the production drawing.

2. Application, Comparative Times, and the Weight Factor

Before referring to specific examples with the approximate times taken to produce them as compared with other methods of manufacture, it will be appreciated that there can be quite an initial saving in plant requirements, due to the fact that, within the limits of the etching tank available, several components may be etched simultaneously.

Fig. 8 shows a panel which, by normal machining methods, took 15 hours to produce, but by contour etching only four-and-a-quarter hours.

The second example — shown in Fig. 9 — is a fabricated component consisting of two plates flush riveted together, taking a total time of five-and-a-quarter hours to manufacture, whereas by contour etching the time taken was four-and-three-quarter hours.

From this particular specimen, too, yet another point in favour of contour etching emerges — that of weight saving. It will be appreciated that an integrally constructed component of this nature is very much stronger than a fabricated item ; therefore,

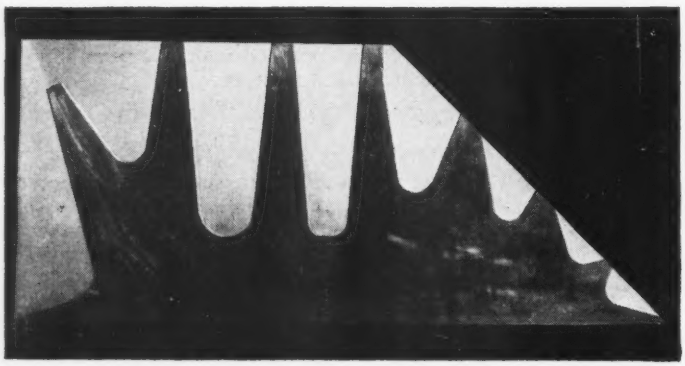


Fig. 9. Fabricated component consisting of two plates flush riveted together, taking a total time of 5¼ hours to manufacture, against 4¾ hours by contour etching.

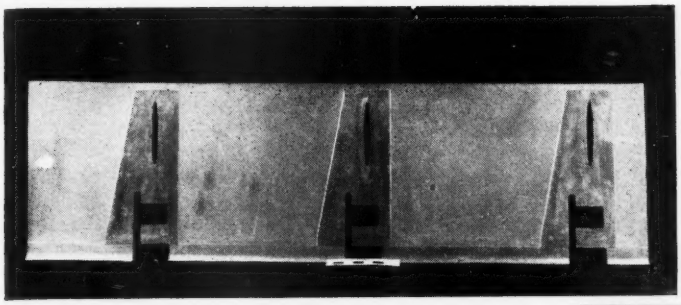
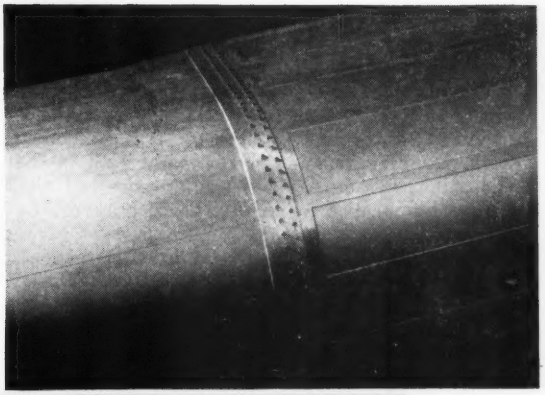
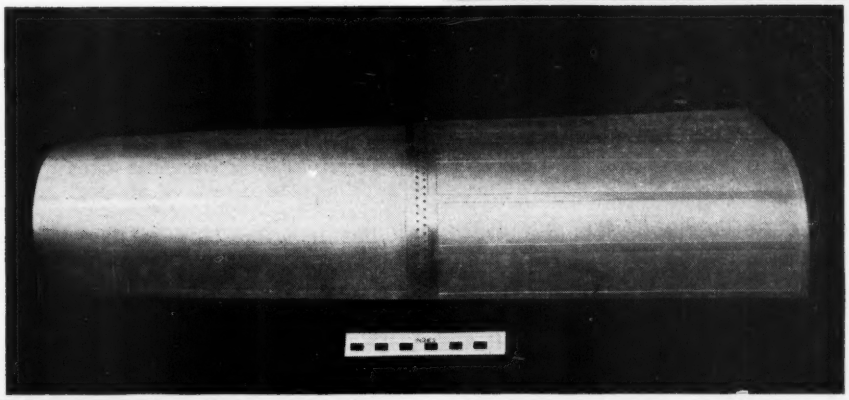


Fig. 10. Panel with varying depths, produced by contour etching in six hours.



Figs. 11 *(right)* and 11a *(below)*. Another application of contour etching.



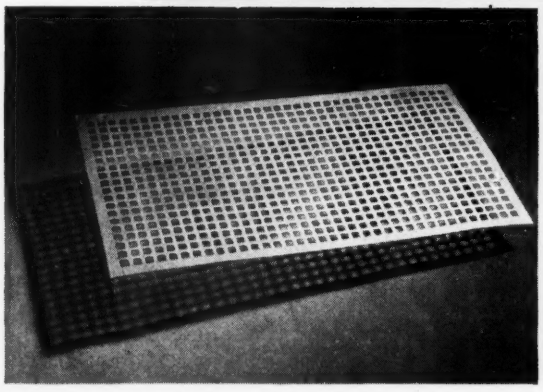


Fig. 12. A .006″ thick plate etched to form a grill, produced quite economically by chemical methods.

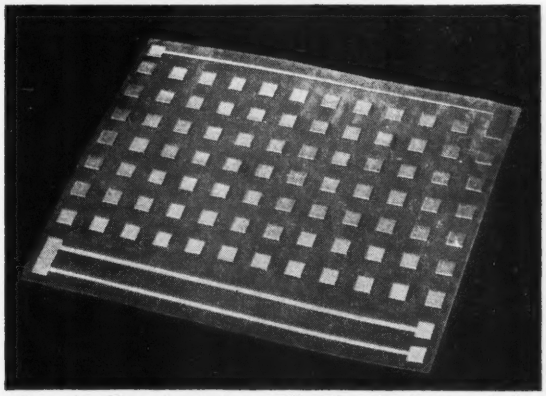


Fig. 13. Plate bonded to a fibreglass laminate and then etched away to the required pattern.

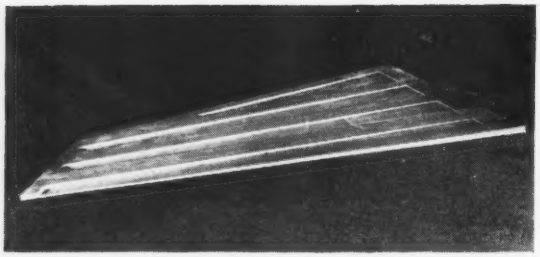


Fig. 14. A .18″ thick panel reduced to .05″ within a prescribed pattern.

by decreasing the gauges of material, a reduction in weight for the same strength may be obtained.

Fig. 10 illustrates a panel with varying depths which it would be impracticable to machine as 75% of the skin is only .01″ thick with a leading edge of .036″ from the original plate of .064″. To produce this by contour etching took six hours.

Reduxing would possibly be the alternative method, and to manufacture by this means the estimated time is approximately nine hours, on top of which, of course, there would be the cost of a bonding fixture and tooling for the detail parts as opposed to the cost of masking, plus an 18G stencil template.

Another application is shown in Figs. 11 and 11a and, in this instance, the etching was done after forming and includes a buttstrap etched into one plate, thus saving weight and cost by omitting two lines of rivets. Producing this component by contour etching also, of course, dispenses with the detail tooling which would have been necessary for the reinforcing strips.

Finally, Figs. 12 and 13 show a more unusual type of component. Fig. 12 depicts a .006″ thick plate etched to form a grill, which would entail the manufacture of expensive piercing tools but which, by chemical methods, can be produced quite economically. Fig. 13 is a plate bonded to a fibre glass laminate and then etched away to the required pattern.

Taper Contour Etching

Figs. 14, 15 and 16 are examples of taper milling by chemical means. This is done by gradual immersion or withdrawal at a predetermined rate from the etching solution.

Fig. 14 shows a .18″ thick panel reduced to .05″ within a prescribed pattern.

Fig. 15 shows two integrally stiffened 'tab' skins prior to bonding, the skin thickness being .01″ with tapered stiffeners and spar member. Remembering that the etchant penetrates under the resist by an amount equal to the depth etched and as the stiffeners are required to be of parallel section in plan view, it will be appreciated that to the nominal width of stiffeners at the thick end of the wedge (t) must be added at each face to be etched an equivalent amount to the depth of etch at point (a) — see Fig. 15a.

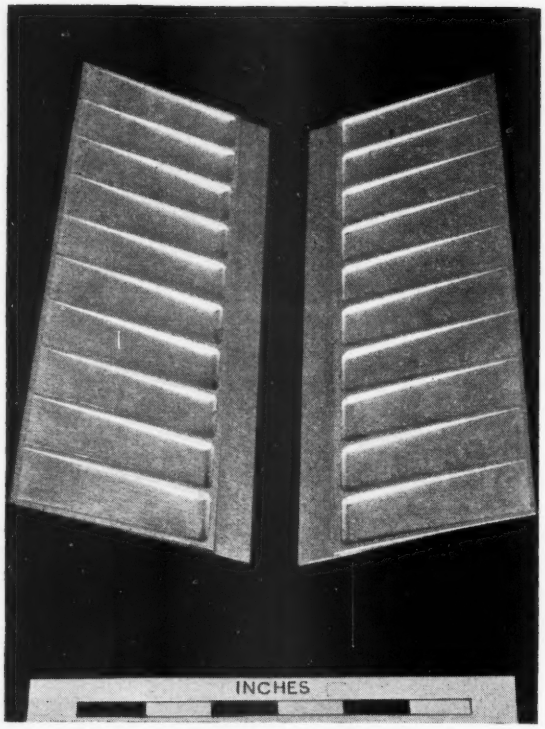


Fig. 15. Two integrally stiffened 'tab' skins prior to bonding.

This was achieved by first tapering the plate, then reversing the direction of entry and tapering the pockets after remasking.

Fig. 16 is the longest tapered component so far produced at Saunders-Roe, and is 4′ 6″ long, tapering from .06″ to .01″; the etching being done on the inside of this member after forming to channel section.

3. Physical and Mechanical Effects

Materials which are age-hardened give a much finer surface finish than those in the solution treated condition. This is probably due to the greater rate of differential attack on the softer material; also the finish on the copper based alloys is superior to that obtained in those containing a high percentage of zinc, such as DTD.687, due to the zinc being more susceptible to attack by sodium hydroxide. Comparative surface finishes are shown in Figs. 17 to 20 inclusive.

Examination by high magnification has revealed that in materials to specifications such as L.72, L.73, and DTD.687 reduced in thickness by contour etching with the sodium hydroxide solution, there is no inter-granular attack or modification to the structure below the etched surface. With L.65 it was found that the deeper the etching was taken, so the pitting increased in the direction of the end grain,

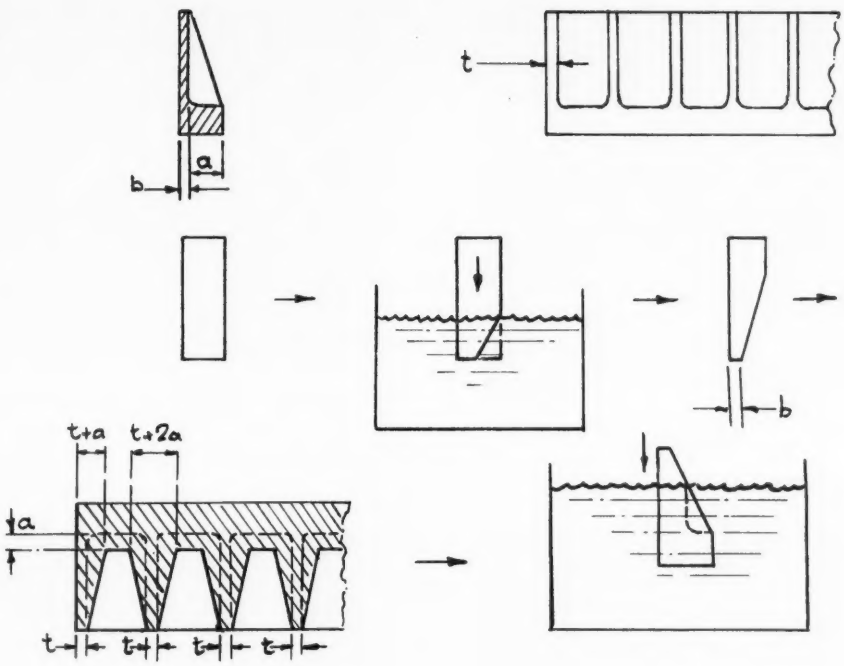


Fig. 15(a). This diagram illustrates the manner in which a tapered part can be produced by etching. The degree of taper is controlled by the rate at which the plate is immersed in the etchant. By suitably masking the tapered face and immersing the wedge again in the etchant, base first, stiffeners of constant width, connected by a skin of constant thickness, can be produced. The shape of the required part is shown at the top.

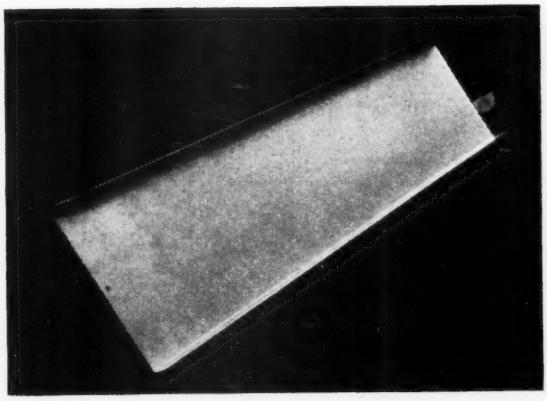


Fig. 16. The longest tapered component so far produced at Saunders-Roe, 4′ 6″ long, and tapering from .06″ to .01″.

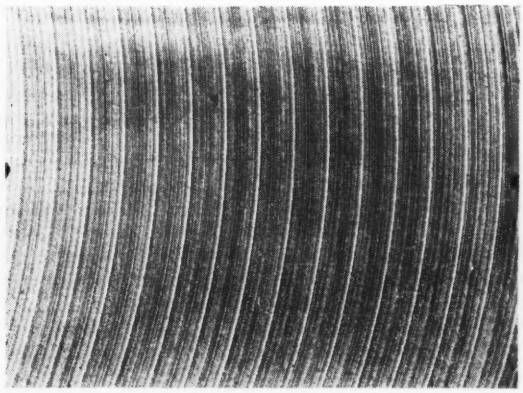


Fig. 17. Machined surface x 10.

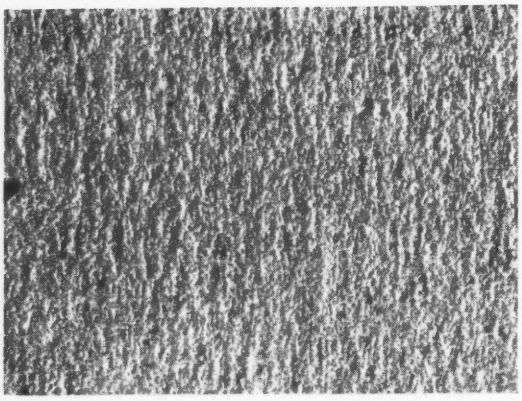


Fig. 18. Contour etched DTD.687 x 10.

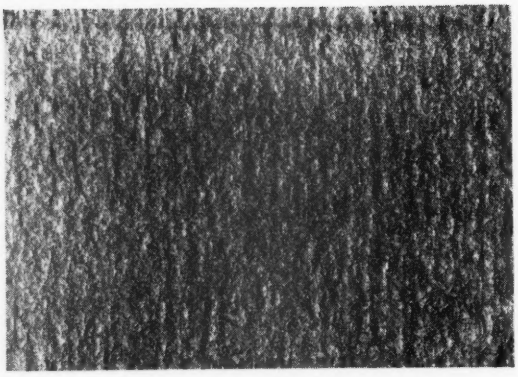


Fig. 19. Contour etched DTD.610 x 10.

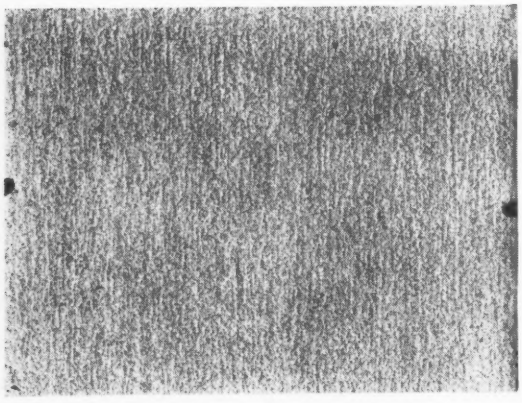


Fig. 20. Contour etched DTD.646 x 10.

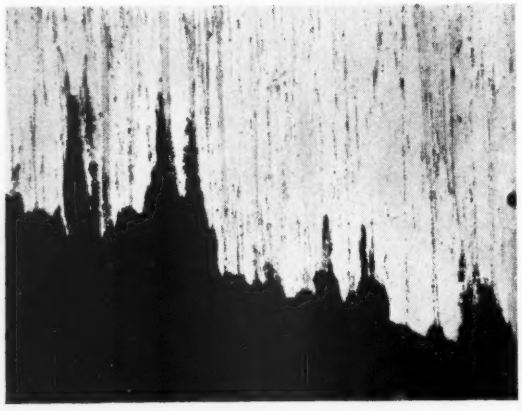


Fig. 21. Section through an L.65 block etched to a depth of 1″.

and Fig. 21 shows a section through an L.65 block etched to a depth of 1″. It can be seen that, although the majority of the fissures have the rounded bottom of chemical attack, there are signs of stress corrosion cracks in one or two. This, of course, would affect the fatigue life of a component but, as they are only of the order of .030″ deep, they could possibly be polished out.

Bending fatigue tests on specimens as indicated in Fig. 22 are being carried out on materials in the 'as received', machined, and contour etched conditions, and the indications are, that the number of loading cycles to failure of specimens produced by contour etching is of the same order as that for machined specimens.

The table given overleaf shows the initial fatigue tests carried out on L.71 material.

All the specimens, except one, were tested at a stress level of ±24,000 lb./in. and gave cycles to failure as shown.

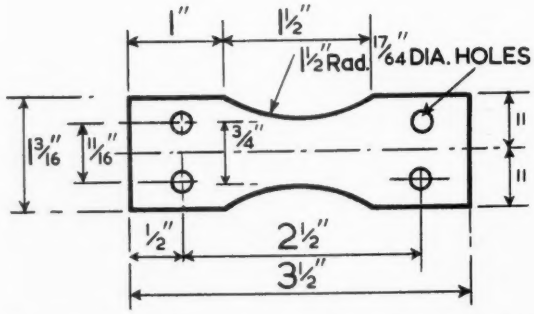


Fig. 22. Dimensions of the fatigue test-pieces cut from a 10 swg sheet. The thickness of the machine-milled and contour-etched test-pieces was reduced to .08″.

Specimen No.	A		B		C		D	
	Unmachined		Machined		Contour Etched		Contour Etched and Vapour Blasted	
	t ins.		t ins.		t ins.		t ins.	
1	.126	.....	.085	223,600	.085	229,800	.084	351,300
2	.127	417,700	.085	370,100	.084	180,500	.084	270,000
3	.127	775,700	.085	222,400	.084	228,300	.083	208,500
4	.127	360,000	.085	254,800	.085	221,700	.083	620,500
5	.127	330,900	.085	133,900	.084	201,900		200,300
6	.127	309,900	.085	178,800	.085	171,900		

"RECENT ADVANCES IN THE APPLICATION OF RESISTANCE WELDING TO AIRFRAME CONSTRUCTION"

(*concluded from page* 252)

2. *Effect of Sheet Strength*

Aluminium Alloys: Stressed attachment 17%' loss. Unstressed attachment 10% loss (Ref. 12).

Titanium: No loss.

3. *Other Factors to be Considered*

Effect of pitch on strength: see Refs. 7 and 8.
Effect of unequal thicknesses: see Ref. 7.
Load distribution: see Ref. 7.

4. *Fatigue Strength*

The machine settings used are designed to give maximum static strength and consistency. Very little work has been done with the object of improving fatigue strength. For most applications, fatigue life is limited by the riveted joints used for final assembly rather than by the spot welds.

Where an advantage can be realised by increasing spot weld fatigue strength, it seems likely that this can be done either by choice of settings based on fatigue tests or as suggested by Welter (13) by pre-stressing.

A large number of fatigue tests on structural joints between spot welded assemblies has resulted in few if any failures originating at spot welds. Service experience on pressure cabin lap joints (2) has been satisfactory.

Ref. 11 shows a loaded spot weld to give an effective stress concentration factor of two to three. This is confirmed by unpublished Handley Page Limited tests.

According to Fisher (Third Annual Conference of the International Committee on Aeronautical Fatigue) the average value of theoretical stress concentration factor for a distributed structural joint using rivets or bolts is 5.0.

REPORT AND DISCUSSION

Chairman: S. P. WOODLEY, M.B.E.

The **Chairman:** The Paper on magnesium has been extremely interesting. I feel that those concerned need a much better sales service. We are always seeking means of reducing weight, but we who build naval aircraft are worried about corrosion. From the remarks made this morning, it would appear that Mr. Wilkinson sells something, and I feel that he needs to push it a lot harder with the aircraft manufacturers. One thing that worried me was that most of his illustrations were of American aircraft. Does that mean that the Americans are further ahead in the metallurgical sense, or have they more competent materials-tackling design people?

It is a little difficult for me to comment on the second Paper. I have a certain bias in that direction. I should like to know a lot more about welding titanium. We feel that perhaps the orthodox light alloy structures are gradually disappearing to be replaced by steel or titanium.

I have some diffidence about making any comments on the third Paper. There is no doubt that this has a tremendous future. I should have liked a little more information on making the tools and the masks. I think that is where some form of profile contour machine will help us. One point not stressed, but a very important one, is that when a comparison is made of etching times against machining times, there is also a tremendous saving on the subsequent hand finishing required after the machining operation.

Mr. R. E. Mills, M.I.Prod.E., A.F.R.Ae.S. (*Specialist Designer (Mechanical), A. V. Roe & Co. Ltd.*): My questions are concerned with contour etching, and I hope Mr. Sheppard will forgive me if I am a little critical. As an old colleague of mine, perhaps he will appreciate the way in which the remarks are made.

First of all, I get the impression that the process has great possibilities, but as it has been described, I feel that it is very much in the initial stages of development. I should therefore like to ask one or two questions about it.

First, the method of stripping appeared to me to be a little crude. I should have thought that cutting with a knife might set up fatigue cracks. I wonder whether there is another method, even a chemical one, whereby the stripping could be done. Secondly, I thought that five minutes for washing was perhaps a little on the short side. In that connection, I should like to ask whether any prolonged tests have been carried out to prove that that period is satisfactory.

On the question of surface finish, I felt that the examples were a little nebulous. Could you give some C.L.A. values of surface finish so that we have a recognised standard to work to? On the same subject, I thought your written remarks were a little in contradiction to Major Teed's views on that subject.

Mr. Sheppard: First, we have found the process of cutting by the knife most satisfactory. It is true that if the operators are not careful, they can penetrate too deeply and score the plate and that will then etch in progressively and can cause stress trouble, but the girls become quite proficient in this work and they can cut through the material without marking the metal.

As to removing the resist by chemical means, the resist itself is resistant to acids and alkalis, and so that is out.

With regard to corrosion after the cold and hot water washes, we have had pieces of plate lying around the factory for as long as two-and-a-half years, and there is no sign of any corrosive action.

As to finish, as far as we can judge on the age-hardened plate we are in the region of 24 - 25 micro-inches. On solution treatment we are in the range of 100.

Mr. E. Craker (*Production Research Department, Folland Aircraft Ltd.*): Could Mr. Wilkinson enlarge on the technique of resistance heating? When stretch forming over a hot tool, the material is held in cold jaws and there is a temperature gradient in that part of the material between the tool and the jaws. The elongation takes place only in that area of the material which is in contact with the tool. If resistance heating could be used, more effective elongation could be obtained from the material between the tool and jaws.

In his Paper to the Institute of Metals, Mr. Wilkinson made reference to the use of d.c., implying that it might have some advantage over the use of a.c.

There is also the matter of the use of glass cloth as a lubricating medium. Would there not be some tendency for the cloth to pleat up underneath the metal as forming took place?

Mr. Wilkinson: I am not an electrical engineer and, therefore, I shall have to ask for notice of your question about the use of a.c. or d.c.

(*In his written reply, Mr. Wilkinson says*:

I am grateful to Mr. Craker for drawing attention to an error in my Paper. Either low voltage a.c. or d.c. can be used. In practice, however, it is more convenient to step-down mains a.c. by transformer.

On the general question of resistance heating of sheet, I now learn that it has recently been found on titanium that this method — whilst satisfactory for square or rectangular shapes — gives unequal heat distribution on more complex forms.)

On the question of the use of a fibre glass blanket, no doubt puckering or creasing might well be expected, but in practice it happens to work.

Mr. S. G. E. Nash, M.I.Prod.E. (*Deputy Chief Development Engineer (Metals), Bristol Aircraft Ltd.*): Spot-welding was held in ill repute for some time. It is an excellent thing that the statement which has been made this morning should have come from a welding engineer, particularly when one considers that few topics have received as much attention on the research side as spot-welding over the years. A lot of that ill repute came from the performance of spot-welded structures in an unfavourable comparison with riveted ones in the matter of the accommodation of strain. I would ask Mr. Gardner to comment further on the present situation with respect to that, and particularly with respect to the tendency of failures in spot-welded structures to run once having started. In a lot of the earlier work there was a tendency, if one of two welds failed under structural loading, for the whole thing to unbutton like a waistcoat.

Mr. Gardner has made interesting references to new régimes and to stainless steels. One of the big disadvantages of resistance welding in these circumstances is the very high pressure which must be applied. Yet if one is to build aircraft successfully one cannot always have the component in panel form taken to the machine and, therefore, one has to have portable equipment. Is there much hope of being able to reduce the pressures necessary for stainless steel working in these portable applications?

With regard to contour etching, there is not very much reference to curved panels. Most people interested in contour etching are very much interested in the patent situation. The American patents reside very largely in the applications to curved surfaces. I should like to have Mr. Sheppard's views on this subject, and also information about published work relating to the process on steel and titanium.

Mr. Gardner: With regard to the waistcoat unbuttoning, I can only answer from my observation of structural tests on a large number of aircraft components, in which spot-welding was used for attaching stringers to sheet and for attaching the corrugated core to the face plate of a sandwich construction. There were no failures which started as a result of a spot-weld failure. However, failure can occur as a result of severe buckling of the sheets. I recall that in one case one spot-weld went, and then about two or three more, but not immediately — at successive increments of loading. On the corrugated construction, the spot-welds do not fail until a very high stress is reached. Then instability failure probably results in quite a large number of spot-welds going. But the design keeps that in view, and design stresses are adequately below the stress at which that happens.

It has to be borne in mind that a spot-weld is a much stiffer attachment than a rivet, especially if you are designing a lap joint. If it was found necessary to have more than two rows of welds in a lap joint, it could not be assumed that the load was taken equally by each row (which, because of its greater elongation, can be assumed in the case of a riveted joint). For the same reason, you cannot mix spot-welds with rivets in a joint.

I do not feel very qualified to answer your question about portable equipment. As it stands, the spot-welding of aircraft structures is for portable sub-assemblies to which there is access from both sides. I do not think there is any possibility of portable equipment for aluminium alloys. It still seems rather unlikely to come in the case of stainless steels, but I cannot give you a definite answer.

(Author's Note:

I have since been informed that portable spot-welding equipment has been successfully used for fabrication of stainless steel components for jet engines. It would appear that for stainless steel spot-welding, a portable machine can be devised to do practically any job which can be done with a pedestal type machine. For aluminium alloys, however, many problems arising from the very high currents involved remain to be solved before portable equipment will be available for producing spot welds to the standards required for aircraft production).

Mr. Sheppard: There is an American patent on the manufacture of high strength lightweight curved structures by etching, irrespective of the etchant or masking medium used, so, assuming the validity of the patent in this country, to etch a curved structure would possibly be an infringement.

With regard to steels and titanium, most of our work has been in the light alloys, but we are interested in, and pursuing the possibility of, etching steels, titanium, and magnesium; these materials are more difficult and expensive to etch, because the etchant is acid as opposed to alkali for the light alloys.

The acid is a consumable item, and the exothermic reactions make temperature control more difficult, necessitating the use of heat exchangers. There is also the problem of what material to use for the tanks, holding rigs, and pipes, etc.

With titanium we have tried a mixture of hydrofluoric and nitric acid to try and cut down hydrogen embrittlement, another major problem in the etching of steels.

The etching of steels is still in the experimental stage, and I think it will be some while before we are in production here and in America.

Mr. H. J. C. Weighell, Wh.Sc., A.M.I.Mech.E., A.M.I.Prod.E. (*Production Methods Superintendent, Sperry Gyroscope Co. Ltd.*): First, I should like to ask Mr. Wilkinson what the model is that he has in front of him on the table.

My second question is addressed to Mr. Sheppard, and it relates to Figs. 12 and 13 in the Paper and the square grid type of etchings. I should like to ask whether he prepared the surface for these by removing the resist material after meticulously cutting all round with a knife, or whether he had a better method.

Mr. Wilkinson : The model is one used for an S.B.A.C. Weight Control Exhibition some years ago. It was devised and manufactured by one of our large aircraft Companies which is using something like 1,300 lb. of magnesium alloy sheet on an aircraft. The purpose is to show that for normal values of shear flow you can have a magnesium panel which is only 71%, of the weight of the aluminium panel corresponding to it. If you twist the screw, you will find that the aluminium panel will start to buckle in compression rather before the magnesium panel.

This is, perhaps one of the best ways of using magnesium. We do not claim that magnesium can be used in many other applications where very strong aluminium alloy, such as DTD.687, clearly has better specific tensile and compressive properties. Indeed, if you have very high shear flow, then it is probable that a high strength aluminium alloy is better.

One of the points that I have made in my Paper, however, is that, in contradistinction to using magnesium for the primary structure of aircraft, there are virtues in its use in the secondary structure.

Mr. Sheppard : Figs. 12 and 13 relate to experimental components. The one in Fig. 12 is 0.006" thick, and that is about the maximum thickness of the plate through which you can go while getting vertical sides to the slot. We should not use our normal masking. We should use a photo-sensitive resist and acid etch.

Mr. W. S. Hollis, B.Sc.(Eng.), A.F.R.Ae.S., M.I.Prod.E. (*Assistant Director, Aircraft Production, Ministry of Supply*): I wonder whether it is generally known that the Gas Turbine Calibration Committee, which deals generally with aero engine firms, has, through the Welding Panel, recently completed a manual of welding practice which covers all the welding applications. The manual has been approved by the Director of Materials and also by the A.I.D. If the circulation has not yet covered aircraft firms, we should be very pleased to make the publication available. It covers very much the lines of the lecture and it deals not only with the practice, but materials as well.

I should also like to make a point on the question of magnesium alloy bearings used in the last War. In certain gun turret support rings which were relatively lightly loaded we used magnesium alloys exclusively. They were chromated. The manipulation of the turret took the chromate off the track, but the track considerably work-hardened and the polishing effect maintained that work-hardening. I cannot recall a single case of failure or corrosion occurring when using magnesium alloy as a bearing material.

Mr. Wilkinson : I thank Mr. Hollis for bringing up that point — it is very true. The de Havilland Gipsy series of engines has used a cast bearing housing for the camshafts for, I suppose, upwards of 20 years. I was at de Havilland recently and I looked over their overhaul line and I was told that failures in service have been rare. Admittedly, the bearing loads are fairly light and the lubrication is good. However, under those conditions Mr. Hollis is right in saying that magnesium is a good bearing material.

Mr. G. H. Taylor (*New Development & Process Engineer (Aircraft), The English Electric Co. Ltd., Preston*): I wish to ask Mr. Sheppard two questions.

First, is there any difference in the formation of the boundary edges of the etched surface when etching clad or unclad material? Do you get a different attack in the shape of an angle or a radius equal to the depth penetrated?

Secondly, do you protect the edges of the sheet or plate against a breakdown of the resist when it is applied by taking off all sharp corners? Is that necessary?

Mr. Sheppard : The answer to the first question is that we find no difference at all.

Your question about protecting the edges is rather a good one. We now have a method of taping which we use to seal the edges. Originally we found it was a very good safety factor to leave the edge of the component full, and trim after etching. Although we now use a tape, we still endeavour to seal the edges with the resist as a further safety precaution.

Mr. H. G. Cole (*Ministry of Supply*): Mr. Wilkinson remarked on the greater exploitation of magnesium alloy sheet in the United States than in this country. I wonder whether one of the reasons is that the Americans have put all their energies into developing the high purity type of sheet which has a very high corrosion resistance, whereas we have put our faith in the magnesium-zirconium sheet with higher strength but poorer corrosion resistance. The Americans have gone ahead in the last 10 years on their sheet, and we are very much behind. I think there is more explanation for this than is given in the Paper.

Mr. Wilkinson : There is a deal of truth in what you say. However, I think we might look briefly at the development of magnesium sheet alloys in the United States and over here.

Here and in the United States almost from the word "go" we have had one alloy, the magnesium-

1½% manganese composition, the lowest strength magnesium sheet alloy. We used that during the War extensively for fuel tanks (oxy-acetylene welded) and it was used for similar applications in the United States.

We rather lagged (in time) behind the United States in the commercial marketing of a higher strength magnesium sheet alloy. The Americans did rather daring things with their alloy. They made some tail-booms for a military aircraft by welding, and unfortunately the aircraft broke up because the booms stress cracked.

After a period, the Americans said they had a new sheet alloy. Instead of 6% aluminium and 1% zinc, as before, the new one was 5% aluminium and 1% zinc. This was believed to be better. Somewhat later they introduced another sheet alloy — 3% aluminium and 1% zinc. This alloy has proved resistant to stress corrosion in service. All these alloys were, I believe, in high purity form.

It is a characteristic of the magnesium-aluminium-zinc type of alloy that if you hold the iron and nickel impurity limits down to certain values, you get a very much more corrosion-resistant material than you have if you have more of these impurities. Measured by weight loss in a spray test, or a total immersion test, this high purity AZ.31 gives a very satisfactory performance. In fact, if you have a sheet specimen in a salt solution, whether spray or total immersion, and leave it there a few weeks and then take it out and measure the weight loss, you will find that the weight loss is very small indeed. When you examine the specimen, you will see that there is hardly any attack on the broad surface, but you may find some deep pits. These are purely adventitious: you may have some cathodic impurities which have "crept" into the melt. However, if you use the material in thin sheet form, as for control surfaces, one deep pit may be castastrophic in the end.

In this country we concentrated our early efforts on a magnesium-zinc-zirconium alloy which is also of high purity. It has somewhat higher original strength values and, especially after preheating for hot forming up to 300°C., it has considerably higher *residual* strength values. In other words, the preheating-letting-down-annealing effect in the hot forming is lower for our alloy than for AZ.31.

On the corrosion angle, this magnesium-zinc-zirconium alloy shows a considerably greater weight loss after a spray test or a total immersion test. But that weight loss is uniform across the whole surface of the sheet. There are usually no deep pits.

(Author's Note:

Since presenting the Paper, there has been some comment on my earlier remarks that we had lagged behind the United States in regard to production of high purity AZ.31 sheet. This is true *in time*, but I should like to make it quite clear that this high purity material has been manufactured in the U.K. for quite some years now, and that it is in aircraft use in thin gauges. A main reason why it was introduced here was that the magnesium-zinc-zirconium alloy is somewhat difficult to roll in gauges thinner than 18-20 s.w.g.: it was not that the particular applications demanded maximum corrosion resistance. We have every respect for American use of high purity AZ.31 and for the intrinsic virtues of the alloy in its anti-corrosion performance. However, we do not like the pitting tendency, and we prefer the mechanical properties of the zirconium bearing alloy. Also, we reckon that magnesium sheet in aircraft has to be painted anyway and that — with good maintenance — differences between alloys in total weight loss under corrosive conditions assume an importance subordinate to other factors).

Mr. Wilkinson then showed a number of slides of illustrations from his Paper, as follows:

I mentioned in the Paper that in America they are using a lot more magnesium sheet, and our Chairman drew attention to this. Fig. 11 shows a production line at the works of Brooks and Perkins Inc., of Detroit, of the tail cone of the Boeing B.47. I think more than 1,000 have been built. This photograph was rather intriguing to me, and so I tried to find out whether Boeing were satisfied with the use of magnesium.

I have a letter here from one of my friends saying that on the B.52, the successor to the B.47, some 4,500 lb. of AZ.31 sheet are used. There is considerably more sheet on the B.52 leading edges, the trailing edges, flaps, etc., than on the B.707.

When we come to the B.707, which I suppose has a "certain civil potential", my friend writes that the outer skin of the leading edge of the Boeing 707 is made from AZ.31 sheet and the inner skin is made from 61.S aluminium. The magnesium skin is riveted to the aluminium inner skin, but it is now said that it is possible for this to be bonded. Heated air is employed for de-icing on the Boeing 707, and the material used for the ducting is stainless steel. The ducting does not touch the outer magnesium skin but is attached to the inner aluminium rib.

This shows that the Boeing Airplane Company, who "know their onions" in regard to aircraft, seem to have established a successful series of applications of magnesium. It is perhaps no breach of confidence to say that I have recently been approached by two large aircraft companies in this country who have heard, on the "jungle telegraph", that Boeing are using magnesium for an aircraft which is going to be used on one of our own airlines.

What the Chairman has said is right. If I had 20 chaps preaching the gospel instead of five, I should be a very happy man. We are doing our best to pack 48 hours into 24, but we just cannot do it.

I should like to take this opportunity of commenting on some more of the illustrations used in my Paper.

Fig. 12 shows the Lockheed F.80C, a standard jet trainer of the United States. It is normally made with its wings and fuselage in aluminium.

Fig. 13 (upper) shows the conventional aluminium alloy wing, and Fig. 13 (lower) shows the magnesium wing which was made by East Coast Aeronautics Inc., of Brooklyn.

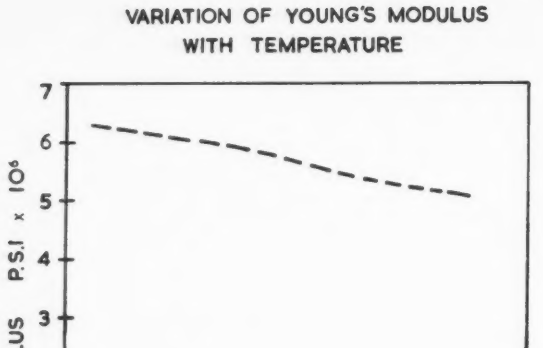
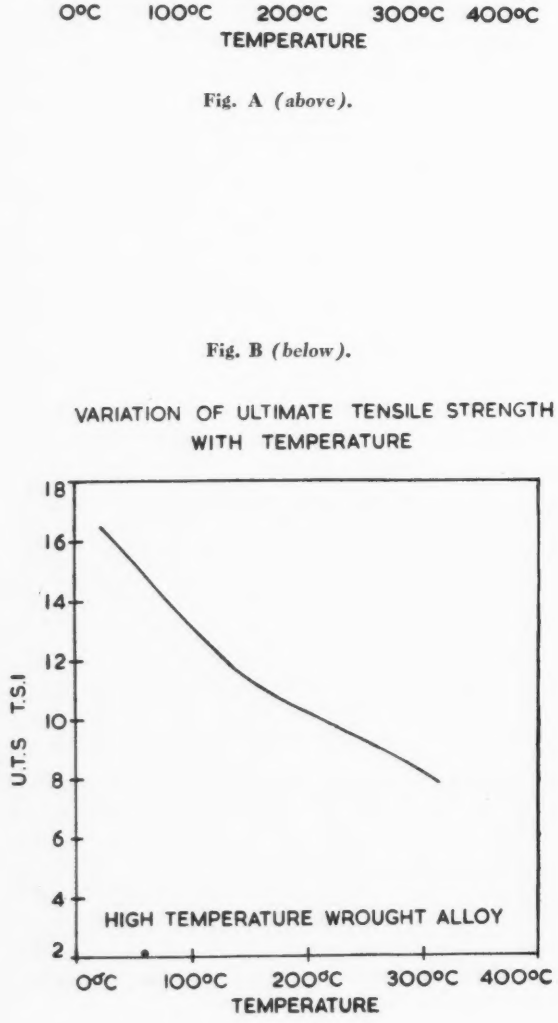


Fig. A *(above)*.

Fig. B *(below)*.



The table in Fig. 14 shows what, in my opinion, is the best way of using magnesium. East Coast Aeronautics say that they like to use magnesium not only to save weight, but to save man-hours. By using thicker magnesium instead of thinner aluminium, the number of rivets is reduced and the structure simplified. You therefore reduce man-hours. Also — and this harks back to Major Teed's lecture — by reducing the number of fastenings you reduce the number of stress concentrations which can promote fatigue; and by using thicker magnesium, you can drill-countersink instead of dimpling.

On the standard F.80 aluminium wing you have 1,644 parts, and with magnesium you have only 508. The corresponding figures for fastenings are 42,758 and 16,050.

I have another letter from America to say that the magnesium version of the F.80 has been flying for a year and a half and that it had 45 hours of flight before any mechanical servicing of any kind was required, and it has now flown 300 hours without any trouble attributable to magnesium.

Earlier I did not have time to refer to the new requirements for aircraft materials in terms of areodynamic heating. Up to about a year ago, although the magnesium industry had already developed cast alloys for engine use up to 300 or 350°C. — almost a hot rolling temperature for magnesium alloys — the industry had not introduced corresponding temperature-resistant wrought alloys. But over the last year or so they have had some success (Table III). These additional illustrations (Figs. A-D) deal with the new magnesium-thorium-zirconium alloys with or without zinc, developed in the U.S.A. and U.K., and which compare favourably in properties with certain aluminium alloys up to temperatures of about 315°C. In the United States this alloy is now in service in guided missiles (Fig. E).

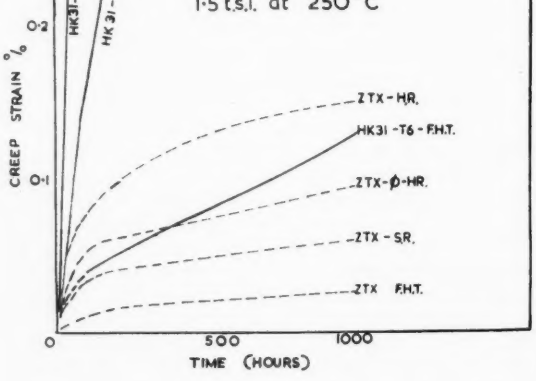


Fig. C

In this country, we have an alloy of this type about to be commercially launched. I think the main point is that at 300°C. the material will have a Young's modulus of around 5.3. Therefore, at supersonic flying temperature you obviously have excellent specific stiffness; that is, if you can use a light alloy at all.

Mr. G. A. Daniell, A.M.I.Prod.E. (*Chief Work Study Engineer, Bristol Aircraft Ltd.*): Relating to a point raised by Mr. Nash concerning pressures in welding machines, can Mr. Gardner tell us whether any significant advances are being made in materials used for electrodes for resistance welding? I imagine that this could be a fruitful field in view of the increased pressures which will be required in the future.

Electrodes in existing materials are not, as Mr. Gardner states, perfectly satisfactory. Mushrooming of the tip frequently occurs, particularly at high production rates. Where accessibility demands a cranked electrode, adequate water cooling is frequently not possible, and this also results in 'mushrooming' and 'pick-up' which tends to defective welding.

The use of the wheel electrode is only possible if there is adequate clearance, which is frequently not the case. Consequently there is, in my view, scope for some advance to be made in this particular aspect of welding by some enterprising manufacturer.

Mr. Gardner: The answer is "No". I do not think I can tell you anything about the subject other than that the high conductivity copper alloys (conductivity 80% - 85% pure copper) have been perfectly satisfactory for aluminium alloy welding, which requires the highest pressures (Rockwell Hardness 70 - 80B). The life of an electrode is quite long, being measured in days, after which its shape must be restored by machining. Perhaps it would be relevant to say that the matter of electrode cleaning is an important aspect of the productivity of a welding machine. Using a conventional spot-welding machine, where you have two electrodes coming together, it is a problem that after between 30 and 50 welds you have formed an alloy between the copper and the aluminium cladding. This is a little pip which you must remove or it will grow quite rapidly and mar surface finish. Removal of this pickup causes an appreciable delay and loss of production. An innovation which makes the problem easier is a roller welding machine. This gives a great improvement in productivity, simply because it is not necessary to have the same pieces of copper in contact with the sheets all the time. In those circumstances, you could probably reckon to weld all day without bothering about cleaning the electrodes. It would probably be three or four days before you had to worry about any change of

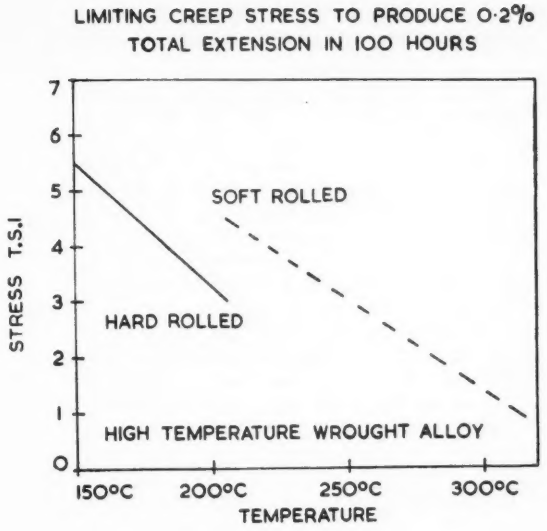


Fig. D

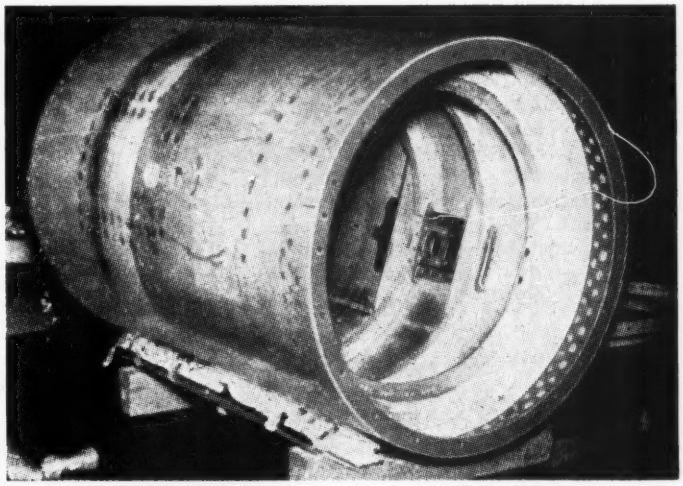


Fig. E

Inner body assembly of a supersonic ramjet engine capable of performing at temperatures above 600°F. The rolled and welded skin is HK31 magnesium.

electrodes, and then it can be done quite simply. The same electrodes can be used again after skimming.

Mr. L. J. Bolton (*Production Superintendent, Hydraulics, Sperry Gyroscope Co. Ltd.*): I wish to put a point to Mr. Sheppard. I noticed in the film that the components were put into the tank in the horizontal position. I presume that this has something to do with the gassing effect. If that is so, how do you go on when you have curved panels so that you cannot present the component into the tank in a way which will overcome the gassing effect?

Secondly, I saw from the film that the operator was spraying on the resist, and it occurred to me that, although he was no doubt doing it fairly uniformly, there must be some variation in the thickness of the resist and some difference in the stiffness. Have you found any variation in the thickness and, if so, does it have any effect? Are you thinking about some means of keeping a uniform thickness, particularly as the resist dries very quickly?

Mr. Sheppard: In reply to your first question, it is preferable to do it in the horizontal position. If put in vertically, there is a tendency to get gas trapped along the top edge, which tends to lift the resist and give bad edges.

I did not say that the resist dried quickly. I said that the strippable coating took about 10 minutes to dry. The resist is cured in an oven for about 30 minutes at 120°C. or 130°C., or less if infra red is used.

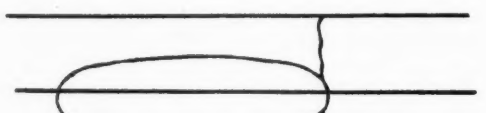
We had some trouble due to varying thicknesses with the spraying, but after a little experimentation the laboratory staff have now modified the mix and it gives us a little latitude which will cope with this difficulty.

Mr. K. E. Cheverton (*Structures Design Engineer, Bristol Aircraft Ltd.*): Perhaps a design engineer might put a design question to Mr. Gardner. It is a question which relates to fatigue in spot-welding. I should like to know what sort of fatigue tests you have done. It occurs to me that you may get fatigue on a compression surface where spot-welding is used, particularly when the compression panel has a buckling skin. I should have thought that with an aircraft the size of the Herald, a buckling skin was probably used. Even if the skin is not buckling, there are the inevitable forces on the spot-weld due to eccentricities. I wonder whether, from the fatigue point of view, spot-welding is a very good means of holding two bits of metal together. Have you any experience of compression fatigue of structures, and also on shear panels if the shear panel is buckling? I have seen cases where the first failure was the heads being pulled off the rivets by the buckling, and the same forces would affect spot-welding.

Mr. Gardner: As to the types of fatigue test that we have done, there are two main cases. There is the wing case, where for convenience we have taken a loading of 25% $\pm$ 7½% of the design load of the spot-weld, the sheets being in fluctuating tension, Under these conditions we got a mean endurance of about 1,000,000 cycles (more detailed results are shown in the graph opposite). I think Mr. Cheverton will agree that that is as good as you could expect from a well-designed riveted joint.

The other type of test is the pressure cabin case, where the loading is from zero to maximum. Boeing and S.A.A.B. have done more work than we have on that case. Boeing's requirement for a pressure cabin case is an endurance of 65,000 cycles under a stress in the skins of about 15,000 lb./sq. in. However, they found that they could readily get a mean endurance, not of the 65,000 cycles that they wanted, but of 125,000 cycles, which meant a very large safety factor over the life of a civil aircraft. That is the case where the spot-weld is doing the job it is designed for — simply carrying shear.

Mr. Cheverton in referring to buckling has put his finger on the worst loading condition for welding.



Undoubtedly, the fatigue failures that occur are nearly always in the area indicated, the crack emanating from the edge of the weld and going out to the sheets. Any "peeling" action between the sheets would accelerate failure. It would be a very bad thing if severe buckling occurred owing to the operating conditions of the aircraft in straight and level flight. If you are using spot-welding, that is a design condition to avoid. Our design methods are such today that it does not occur.

(Author's Note

I am inclined to believe, however, that the spot-weld is no more vulnerable in this respect than the equivalent flush rivet).

We have done some fatigue tests on our sandwich construction, which, under the conventional loading, buckles very little. In fact, you can say that it does not buckle. We applied this loading of 25% $\pm$ 7½% in compression on a section of this construction. Nothing at all happened for about 10,0000,000 cycles. Then we stepped up the loading until finally we had a loading where there was a certain amount of buckling taking place, and after about 25,000,000 cycles some failures started to occur. We went on for quite a long time then, and examined the failures afterwards. Some of the spot-welds already deliberately had shrinkage cracks in them, because that is one of the things that always worries people. (A shrinkage crack

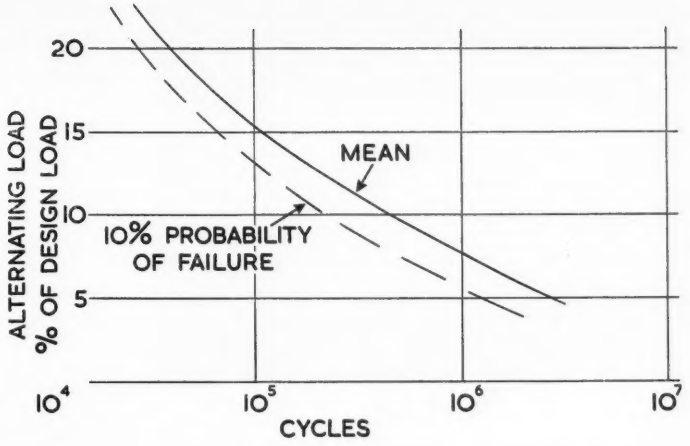
Fatigue Tests on Spot-Welds

Specimens: Two spot tandem lap joints in 14/16 s.w.g. DTD 687.

Design Load: 1,075 lb./spot.

Mean Load: 22.7% of design load throughout.

Curves are based on six results at each load level.



was once thought to be bad from a fatigue point of view.) The specimen had about 30 fatigue cracks in it (none of which had led to failure because it was in compression). Half of them were in plain sheet remote from the spot-weld. All the rest except one emanated from the rivet holes. In just one case there was a crack emanating from a spot-weld.

The reason why we feel very unconcerned about fatigue of spot-welds is that we have now tested about 150 specimens representing all types of construction on Victor and Herald aircraft, all of which have had a large number of spot welds in and have also had some other design features in the way of a structural joint. We have not yet had a failure for which the spot-weld has been responsible.

Mr. H. G. Cole (*Ministry of Supply*): I should like to ask Mr. Gardner what precautions are taken to prevent crevice corrosion.

Mr. Gardner: For spot-welds in clad sheets, even if no precautions at all are taken, we still have no evidence that you get any trouble.

We have had a similar experience to the fatigue case. We have been concerned with a construction which is partly spot-welded and partly riveted, and we have done accelerated corrosion tests in which the outer surface only of the spot-welded joint has been painted in the normal way and no protection at all has been given between the two sheets. The corrosion when it has started has emanated from the rivet holes and the rivets and none from the spot-welded side. (*See photographs on next page*).

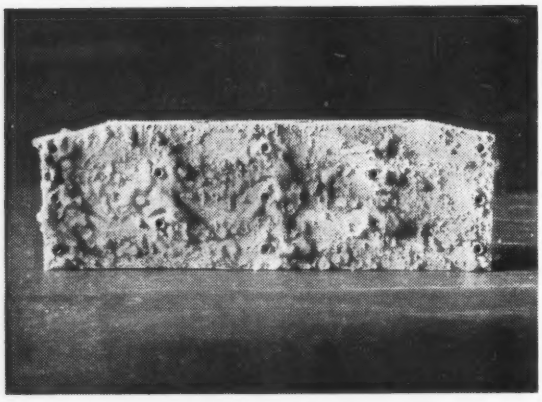
If you feel unhappy about this state of affairs, there is nothing to prevent you from putting a corrosion protection between the two sheets. Strange as it may seem, this is a practical proposition. Whatever corrosion protection medium is chosen is put between the sheets and spot-welded while it still wet. Provided that the spot-welding is done before it is tacky, the electrode pressure is sufficient to push the protection out of the way to make the spot-weld, and it is a perfectly sound spot-weld. Outside surfaces can, of course, be protected in the normal way. Some people who have done this are S.N.C.A.S.E., of Toulouse, in connection with the Caravelle. They have tried putting an Araldite adhesive between the surfaces, and then spot-welding them. The film is used primarily for protection against corrosion and to improve sealing, and not primarily to strengthen the joint.

Mr. Wilkinson: I should like to support Mr. Gardner by saying that with magnesium we have spot-welded through wet films to protect the faying surfaces, with completely satisfactory results.

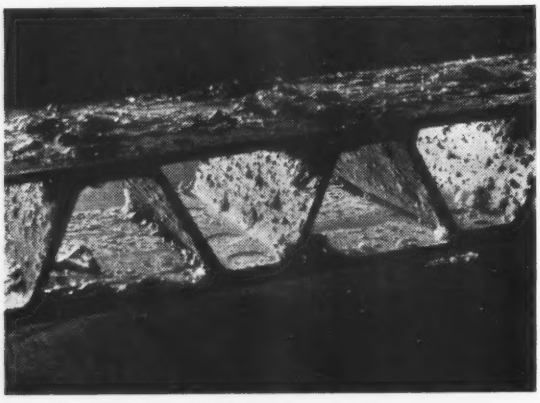
Mr. P. A. Broadbent (*Technical Assistant to Works Manager, Sterling Metals Ltd.*): I should like to correct a statement made by Mr. Wilkinson in his introductory remarks. The Ferguson tractor is painted completely all over. The coating he has referred to is not our normal cast finish.

Going up into the clouds again, I was interested to hear from Mr. Wilkinson's remarks that casting was a hot forming operation! I was rather disturbed to hear that the Americans seem to be better than us in their applications of magnesium in the aircraft industry. On the casting side — I am open to correction on this — I think the Americans can learn quite a lot from us if they want to. We have supplied to one customer about 8,000 magnesium castings a month from something like 600 different patterns. I do not think the Americans do anything like that.

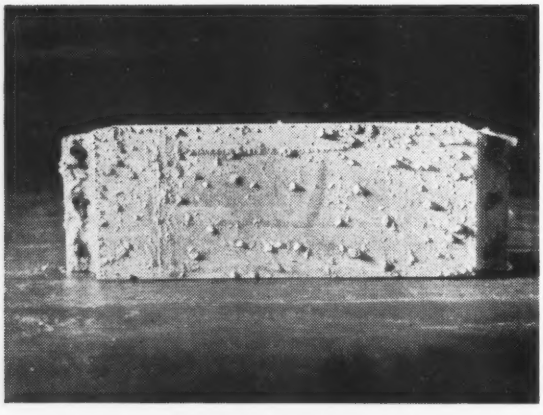
Also, I do not think the Americans do any commercial magnesium. Most of their magnesium founding is for the aircraft industry. Commercial work may not be of much interest to aircraft production people, but certainly it leads to greater production methods in the foundry world, and the Americans can learn quite a lot from us on that point.



Riveted surface.



Close-up through corrugations.



Spot-welded surface.

These photographs of a completely unprotected specimen after accelerated corrosion test bring out more strongly Mr. Gardner's point, made on the previous page. The conditions of test corresponded to at least nine years' exposure to the atmosphere. Painted specimens exposed to the atmosphere for four years have shown no signs of corrosion.

I am now going to contradict something that I have already said by asking whether the designers in this country have ever thought of tackling the problems the Americans have tackled, with particular reference to Osbrink, in America, who casts large surface areas and thin sections of wings about 4′ square × $\frac{1}{8}$″ thick as a casting ? A lot of talk has been going on about methods of machining, spot-welding and so on. I wonder whether casting would overcome all these problems — or would it add more ?

Mr. Wilkinson : If I said that the Ferguson tractor main transmission casting was not painted, I am sorry. I did not mean to say that. I believe I said that the castings on the Volkswagen cars are unpainted. I am aware that the Ferguson castings are painted. However, you always have a lot of tractor drivers with hobnailed boots, and the paint wears off at times.

(Author's Note

In my opening remarks I instanced the Ferguson tractor and the Volkswagen as good examples of the use of relatively unprotected magnesium alloys with reliable service performance. I did this by way of introduction to the description of specialised protective schemes newly developed to meet the more rigorous service conditions now encountered in pressurised, high flying aircraft).

I am grateful for the reference to the American practice of making thin walled castings of large surface area. I have met Mr. Osbrink. I believe that he has got nothing which we in this country could not have, if we had at least one foundry which would take trouble in using high precision patterns and moulding methods. There is no secret in the job. It is a matter of taking care and running very thin sections over large areas, paying the operatives high wages and (justifiably) charging the customers high prices for single-piece components such as air brakes, etc.

(Author's Note

I am pleased to say that I am advised that we do, indeed, have at least one foundry in the U.K. which can undertake such work.)

There has been a demand in this country recently for an assembly of magnesium components which have have been in production in the United States since Korea — Osbrink-wise. The powers-that-be here had two propositions put up to them. One was for an Osbrink duplication, and the other was a mixed construction of castings, chemically milled and welded to magnesium sheet pressings and extrusions. The powers-that-be have decided to chance their arm on the latter instead of the former, which I personally regret. I think it would have been a good idea to have encouraged some company in this country to go ahead and make thin walled castings.

This American equipment has been in American service since Korea in such circumstances that the

whole of the structure, which includes some steel, etc., is periodically sluiced in sea-water. The equipment has been protected with the H.A.E. treatment and — no doubt with very good field maintenance — there has been no corrosion trouble at all.

Mr. J. C. King (*Assistant Chief Engineer (Development), Aircraft Division, English Electric Company Limited*) : I would like to ask Mr. Gardner one or two points with regard to the application of spot welding to civil aircraft and the ensuing fatigue and inspection problems.

Do you consider that spot-welded structures are compatible with " fail-safe " design of civil aircraft ? In that connection, what thought has been given to the problems of inspection and repair? How easy are the cracks you have sketched on the board to find on inspection, in the field or at major inspections, and how will you repair them on the aircraft in service without taking off the complete panel?

You mentioned, and I thoroughly agree, that rivets are not compatible with spot-welds in the same run, because of the stiffness problem and consequently they will not help in taking in shear. In view of the 2% - 3% proportion defective, I wonder how many you replace in manufacture before you fit the component to the aircraft.

In view of all these things, I am doubtful whether spot-welded structures of the type you have described can be designed on the " fail-safe " concept. Do you think it can be done ?

There is also the problem of the inspection and repair of spot-welded structures.

Apropos of the magnesium material, I should like to make one or two comments. Certainly the Americans appear to be using magnesium and magnesium alloy sheet to a greater extent than we are doing, but it is noticeable that they are doing it entirely on secondary structure. I think it may be that they are making use of the lower modulus of magnesium to enable the secondary structure to move out of the way of the deflections of the primary structure. One of the problems in designing secondary structure is that where it attaches to primary structure, you often find the secondary structure buckling and being damaged due to stresses and strains in the primary structure.

I also noticed, in connection with Mr. Wilkinson's lecture, that with the new magnesium alloys, though they give higher proof strength and higher ultimate strength, there is still a low limit of proportionality, and the tangent modulus is low. That, I think, will detract from the use of these alloys to any large extent, unless the limit of proportionality can be put up to nearer the proof stress.

Mr. Gardner : Are spot-welds compatible with the "fail-safe" idea ? We have not designed on the " fail-safe " concept. Our aim has been that you should not get a failure within the life of the part. However, I have spent a little time sitting watching fatigue cracks growing under test on structures typical of what we have on the Herald and the Victor — and you have to sit and watch for a long time. Perhaps half of the life of the specimen is spent with the crack slowly progressing. I have never known the cracks to start from a spot-weld. Normally, when they reach a spot-weld they halt for a while. Thus, although not intentionally, these structures can be regarded as " fail-safe ".

I must be frank. From the " fail-safe " point of view, there is a possible disadvantage. If you have a sheet riveted to a stringer and you have a crack progressing along the sheet, it cannot find its way down the rivet into the stringer, but if it is spot-welded I believe it might. From a " fail-safe " point of view, that might be a disadvantage of spot-welding.

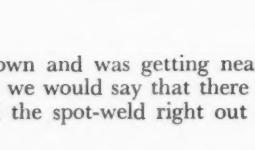
From the point of view of inspection and repair, repair cases must be taken individually. If it is a skin-stringer combination and for some reason some of the spot-welds become damaged in some way, then, since the spot-weld is not really carrying shear but is holding the skin on the stringer, there is no objection to putting in rivets. We have encountered this case once or twice when we have wanted to make an alteration on a test specimen. By taking one stringer off and putting another on, it can be done. The spot-welds can be taken out of the stringer with a rotary file till a smooth surface is obtained, and then half-pitch rivets can be put in to hold the new stringer.

With regard to inspection, I think you probably mean inspection with respect to fatigue failures. That is a problem which is peculiar to the sort of construction that you have. We have a construction where concealed failures are possible, and we have done a certain amount of work on radiography of cracks, and we believe that it can be quite successful. I do not think this problem is peculiar to spot-welding, however.

Mr. Wilkinson : I thank Mr. King for mentioning the tangent modulus. It could not possibly be claimed that magnesium sheet should be used in pure tension instead of the higher strength aluminium alloy sheets. The modulus of magnesium is low. The limit of proportionality is low. The higher the sensitivity of your extensometer, the lower is the limit of proportionality.

The main point about using magnesium sheet is to gain stiffness. The modulus of magnesium is $6\frac{1}{2}$ million lb./sq. in. as against 10 million for aluminium and 30 million for steel. Therefore, you have to stiffen your magnesium by increasing the depth of the section. This rarely arises for castings because, apart from Osbrink, the wall thickness of a casting is usually rather thicker than it need be stress-wise, but for extrusions and sheets you have to increase the moment of inertia, and that increases in proportion to the cube of the depth of a section, or thickness of a sheet, and only in linear proportion to the width. Therefore, with the low specific gravity of magnesium, 1.8, you can obviously do it (if you have room to do it) with a beam. With sheet it is purely a matter of thickening up the sheet to get the stiffness, and you generally have room to do this!

Mr. Gardner : I did not completely answer Mr. King's question about the 2% - 3% defective proportion and what we do with it. We have proved by test that normally a proportion of 2% - 3% defective welds in a large panel with, say, 3,000 welds is not of any importance, but there is occasionally a case where it occurs in a critical area. Each case must be taken on its merits. If there were two adjacent spot-welds absent or very much below strength, it would be possible, if there was room, to half-pitch spot-welds between them. If the pitching is already the minimum, it is possible to spot-weld over the defective ones. (This is a special technique.) Shrinkage cracks are rare, but, looking at a plan view of a spot-weld, if you had a crack which had reached



the extent shown and was getting near the edge of the spot-weld, we would say that there is nothing for it but to drill the spot-weld right out and put in a plug.

Mr. King : If I might reply to the point about stiffening, you do not stiffen a sheet if the moment you stress it the stiffness drops off, which is what happens with the low limit of proportionality.

ADDENDUM BY MR. GARDNER :

It has been my aim to dispel all doubts that spot-welding can be made reliable. I should have preferred to deal more fully with the process itself. To those who distrust spot-welding, however, this would be of little interest.

I was pleased that the discussion aired the three doubts which most frequently occur to aeronautical engineers when considering spot-welding. The three bogeys are "waistcoat unbuttoning", corrosion and fatigue. Ample evidence is available that good spot-welds properly used give no trouble from any of these causes. This has been proved by laboratory tests and by service experience.

It is obviously possible to run into trouble by misusing the spot-welding process. This is also true of aeroplanes themselves. Past failures no more prove that spot-welding is unreliable than that aeroplanes are unreliable.

If some firms (such as Boeing) have obtained good service from spot-welding while others have had nothing but trouble, the only possible conclusion is that Boeing are using the process effectively while the others have misused it.

Mr. F. C. Bartlett (*Production Director, Heathway Engineering Co. Ltd.*) : Certain of us are not actually engaged in aircraft construction and are rather in the dark about what is meant by some of the things which are talked about and how far they go in application. After the impression which Major Teed gave me yesterday, I feel like making a vow never to travel in an aircraft again, and I am certain that was not the intention. In all humbleness, I suggest that would-be contributors should give a little thought to that aspect in relation to letting us know to what degree some of these things are being applied to aircraft.

I take it that you wish to have at these Conferences a good cross-section of people concerned with industry in one capacity or another. From that point of view, I should like to see tooling brought up in a Paper every year, or dealt with in the form of a brains trust at the end of the session.

Herr Frydag dealt with the question of concentrating on fewer types of aircraft, and reference has been made to making research more centralised. This will become more important, and I feel that the Southampton Section is doing a good job in these matters.

The **Chairman :** Perhaps I, as an impartial Chairman, might answer the remarks which have just been made. I hope you will go away feeling happy about flying in aircraft.

You would be surprised at the surface finish that we have to achieve on modern high strength alloys. It would be true to say that on machined items we scour them all over and try to achieve a surface finish of between 12 and 14 micro-inches.

Mr. Bartlett mentioned tooling. The most important thing we have to do is to throw tooling away, which is the most important reason for numerical control.

On behalf of the Institution, I thank our three speakers for the Papers which they have presented to us.

The vote of thanks was carried by acclamation.

CONFERENCE SUMMING-UP—(*conclusion*)

regard to the particular Paper or discussion. That may not be original, but I feel that very often we have to get away from the stereotyped approach to Conferences of this nature.

The **Chairman** thanked the University for providing accommodation for the Conference, members of the University staff for their assistance, the Authors of Papers and contributors to the discussion, and members of the headquarters staff, including Miss Grover, Mr. Woodford's secretary, and Miss Bremner and her staff.

The Conference then terminated.

CONFERENCE SUMMING-UP

by H. G. GREGORY, Chairman of Council.

Chairman: D. L. WIGGINS, M.I.Prod.E. (Chairman, Southampton Section).

FIRST of all, the theme of the Conference was "New Materials—New Methods". Frankly, have any new materials been introduced to the Conference? You might say that you did not expect any to be. Nor did I. It is not necessary for an industry to wait for a Conference of this sort before it announces any new departures in the way of materials.

In his Paper, Mr. Wilkinson emphasised the importance of magnesium alloys. References have been made to the quantity of magnesium being used in the United States and by Volkswagen in Germany. The question which confronts us is why so much more of this material is being used in those two countries than in Great Britain. In the back of our minds we think we know why we do not use so much of it. This is prompted by such questions as corrosion, inclusion problems or the difficulties of hot forming and manipulation, in which field I do not think that sufficient applications have been made. However, as was rightly asked by the Chairman of the session, is it a fact that not enough salesmanship is being exercised in respect of this all-important material? If such large quantities of this material are being used in the United States and Germany — and we have no reason to doubt it — then there is a question which has not been answered.

Major Teed, in a very amusing and very well presented Paper, gave us a restatement of things in relation to surface finish, the importance of prestressing and other aspects of the problems of fatigue.

There is no doubt that the skill of the designers is very often lost in the approach that we have from a production engineering point of view. Again, I think that is something that we should bear in mind. I think the example given by Mr. King was strictly a production engineer's responsibility.

I think there is also a question whether more time ought not to be spent in perfecting known materials.

Mr. Puckle's Paper on the numerical control of machine tools was a very comprehensive survey and one which created a very brisk and lengthy discussion. Listening to the discussion, it struck me how important it was and how little was known about this all-important subject. The Institution is grateful for the contribution of Mr. Booth in respect of that Paper.

The question "What is the difference between a digital computer and an analogue computer"? has not been answered here, but a famous professor was asked that question and he replied "If you feed in the words "Marilyn Monroe" to a digital computer, you will be given the figures 36, 24, 36; but if you feed them into an analogue computer, you will be given the answer in the form of a shape".

Mr. Gardner's Paper on spot-welding was interesting. It gave us further advances. But, as he said, I wonder whether we have any more confidence in resistance welding at all. Our company uses very little spot-welding in primary structures, although we may in secondary structures, but the fact remains that as engineers we are not altogether completely convinced that it is 100 per cent. reliable, and reliability is an essential and fundamental characteristic of our industry.

Mr. Sheppard's Paper was a first-class one. As he said, the process of contour etching has its limitations. But we have heard so much about this in the United States and elsewhere that it is at least gratifying to know that a really scientific approach to this all-important process is being adopted and that he has come along to our Conference to tell us about his experience. I am sure it will not be the last that we shall hear from that source of information.

It is rather difficult for me to comment on Herr Frydag's Paper. After all, it was not a Paper to show us why we won the War. That was used incidentally, I think, to emphasise his point, and that was concentration of effort. Whether we agree with him or whether we do not is something that I must leave to you, but I feel that often the solutions to these problems follow the natural course of evolution, and if some go to the wall, there must be a reason for it. I do not wish to comment on his Paper, except to say that I feel that it is of great value to get the other person's point of view.

The opening addresses were splendid. The Mayor had a very good brief. The Minister did the Institution a great honour in attending and giving his address.

Finally, I thank the Southampton Section for organising the Conference. In this we should always have forward planning in mind. At this Conference we want to anticipate the problems with which we may be confronted. It is also important to encourage our young engineers to attend.

As a suggestion, perhaps in future we might accept the Papers as read and then throw the Conference open for discussion and publish only our findings in

(*concluded on previous page*)

THE 1956 SCHOFIELD SCHOLARSHIP PAPER

PRODUCTION ENGINEERING AS A TRAINING FOR MANAGEMENT

by H. SCHOLES, M.A., Grad.I.Prod.E.

SYNOPSIS

Industry, with its greater complexity, is demanding higher standards from its managers. This Paper attempts to analyse the problem and suggest a possible answer, by first defining the professions of production engineering and management. Then, the source of men and their training to fill these positions are discussed. The combination of the personal qualities and technical abilities used in the practice of the profession of production engineering suggests that here is the manager of the future.

SINCE the end of the War in 1945, Great Britain has experienced a complete change in the field of education and training. In the education of the child, this has been possible by the Education Acts of 1944 and 1945 ; in the education of the man, this has been due to a re-appraisal by industry and the academic world of the need for, and possibilities of, vocational training (using "vocational" in its widest sense).

This Paper is concerned with two vocations (namely, production engineering and management) out of many, yet two whose importance to and status in the nation has grown tremendously during the past 15 years. Because of this, both these fields have been subjected to an intense spotlight since the War, usually separately, but sometimes their inter-relationship has been acknowledged, for example, in the Anglo-American Productivity Reports.

Looking back through past issues of the Journal of the Institution of Production Engineers, one finds many references to the training of production engineers. It is fit and proper that the Institution should, in setting the standards for the profession, also take a lead in discussing ways of reaching and improving on those standards by better training.

The engineering institutions have also tried to give an introduction to management subjects, by bringing in Industrial Administration as part of the qualifying examinations. The British Institute of Management, by exhibitions and publications, has also propagated the need for better education and training for management.

The purpose of this Paper is to discuss the two fields of production engineering and management, their inter-relationships and overlapping ; the source of men in these fields and how to train them ; the application of that training to their work.

Definitions

(a) *Production Engineering*

In all case studies, be they human or technical, or in fact any problem, the most enlightening stage is usually that induced by the advice: "State the problem". This causes so much thought that one often finds the apparent problem is not really the one which must be solved, but is just a symptom of an underlying cause. The problem here is to define production engineering (and later, management), but the underlying cause of the difficulty is the vague terminology of industry. What I understand by a production engineer may be your works manager, or your industrial engineer, your methods engineer, or your process chemist.

The Institution of Production Engineers defines a Production Engineer as "one who, by reason of education, training and experience in technology and management, is competent to determine the factors involved in the manufacture of commodities, and to direct the productive processes to achieve the most efficient co-ordination of effort, with due consideration to quantity, quality and cost". (Note the references to management and economics.)

The Georgia Institute of Technology defines the professional field of Industrial Engineering as "a classification title for engineers who supervise production departments of manufacturing plants, layout machinery and apparatus, and determine flow of work for the most efficient production ; conduct and interpret time and motion study, devise means and set up programmes to curb industrial accidents and fires, set up personnel policies and procedures and evaluate jobs, and devise and install accounting and inventory control systems".

The Anglo-American Council on Productivity Report on "Industrial Engineering" defines

Industrial Engineering as " the application of basic scientific and engineering knowledge and certain analytical techniques to the methods of operating an organisation in industry and other appropriate fields. It requires investigation into the economic advantages of one policy as against another and implementation of the most suitable procedure for raising productive efficiency. To achieve this end performance and costs need to be checked constantly ".

This is very similar to the Institution's definition of Production Engineer above and is the definition to be taken in this Paper. The introduction of the term Industrial Engineer is quite deliberate : it shows the uncertainty of definitions within the profession of production engineering and also widens the scope of the production engineer himself. Too often, in Great Britain, the term " production engineer " really means " tooling engineer ". If a production engineer, with the opportunities of broadening his field of activities, is deliberately confining himself to tooling problems, he is neglecting the chance of wider experience and a fuller career.

(b) *Management*

" What is this management ? " wrote Sir Walter Puckey ; in spite of, or perhaps because of, the increasing number of books on the subject, the definitions of a manager are many. To me he may be the factory manager, to you the departmental manager, or the owner of a firm or the man in the shop round the corner. Today, most authorities are agreed on the separation of the managerial function (whatever it may be) from the entrepreneural function, which were often combined in the last century.

Sir Owen Wansbrough-Jones defines management as " the control by the few of the operations of the many " ; E. F. L. Brech as " a social process entailing responsibility for the effective planning and regulation of the operations of an enterprise, in fulfilment of a given purpose or task, such responsibility involving :-

(i) the installation and maintenance of proper procedure to ensure adherence to plans ; and

(ii) the guidance, integration and supervision of the personnel comprising the enterprise, and carrying out its operations."

Peter F. Drucker, in defining the work of the manager, analyses five basic operations, namely :-

" A manager sets objectives.
A manager organises.
A manager motivates and communicates.
A manager establishes measuring yardsticks.
A manager develops people."

This is the definition of management activity which this Paper will use, and is, in fact, very similar to that of Sir Ewart Smith, who defines management as " the organisation and control of human activity directed to specific ends ", which emphasises the organisational, the measuring, the human and motivating, and the objective aspects again.

These are the things which a manager does as a manager, whatever else he may do at work : this is the analysis of his managing.

The Human Aspect

(a) *Production Engineers*

Looking back at the definition of production (or industrial) engineering in the last section, the reader will realise that I am discussing here the person performing the functions described, whatever his actual title may be. One can assume that the Institution of Production Engineers attracts to its junior grades those young engineers interested more in production than design or sales engineering : of the graduates and students, approximately 80% enter via the technical college, the majority of the remainder being university-trained men. Thus 80% will have had primarily a practical, and 20% primarily a theoretical, training.

I do not know if any analysis of junior members by size of firm has been made : in view of the greater number of small firms in Great Britain, one would expect to find large numbers of members from small firms. From experience, I would say that junior members are divided between those occupying junior to middle positions in production engineering departments of large firms, and those holding relatively senior posts in small firms. The latter may in fact be holding managerial jobs.

Ability to rise to the position of a production engineer depends on so many things : academic training, practical experience, character, encouragement and opportunity. The general opinion at the recent Graduates' Conference on " Education and the Production Engineer " was that the university is not the best place to begin for a career in production engineering. Yet Professor J. V. Connolly, in discussing those taking the Higher National Certificate in Production Engineering, comments : " the people that the Institution of Production Engineers naturally recruits tend to be those who feel themselves unable to clear the more difficult hurdle " (i.e. the Mechanical or Electrical H.N.C.) " This is clearly not the best type of student for the most exacting job of bringing up the levels and standards of production in this country ".

Being a Graduate member of the Institution and knowing many Graduates, I cannot support this view. The moral is that all kinds of people make production engineers, of all levels of ability.

(b) *Managers*

The best source of managers is of much interest to the country in general and firms in particular. Unless one is introduced into the family business, most men begin by climbing up a functional ladder until one day one finds oneself a manager of some grade or other. The process is gradual and usually unnoticed : this often can have unfortunate effects on the man, who will still retain an over-large share of the functional details and refuse to manage. In his Paper, referred to above, Professor Connolly shows two graphs of the distribution of duties with age

showing roughly the transition from, in this case, technical men to administrative work with increasing age.

A B.I.M. publication states that, in general: "Industry draws its future managers from three main sources:-

Graduates recruited from universities and technical colleges.

Non-graduates recruited from those with no academic qualifications, but with a wider general experience gained in the services or in employment in industry or other walks of life.

Employees from within an undertaking or industry who are recognised as possessing management potential."

Later, the same publication discusses the sources of recruitment in detail, and comments:

"Industry has found that the university graduate, whatever his degree course, but provided he has the right personality, is of substantial value in management, once he has absorbed the atmosphere of business.

"The young men of 20 plus who have stayed at school to 18 plus, and who enter industry after National Service, may now contain a good proportion of the type of potential management recruits who would in prewar years have almost certainly been looked for among non-technical university graduates."

Of the nine firms contributing to this publication, four employ under 5,000, five over 5,000 people, and in general, it is the larger firms who deliberately recruit young men for development as potential managers.

In the U.S.A., according to the A.A.C.P. Report on "Education for Management", "to be a high industrial executive in America is not only eminently respectable, but socially desirable. It is a prevailing opinion that business attracts the best talent from educational institutions, whereas in Britain there is a strong tendency for the best students to find their way in to the Civil Service and the professions generally".

Most managers in Great Britain seem to come up what is known, grimly, as the hard way, although the effort put in by young men today in study and practice is far from easy. To develop managers for the future, more study will have to be made of management and its techniques by the managers themselves: to persevere with that they will require the same strength of character as managers of today have shown in their careers.

Education and Training

(a) *Production Engineers*

Can any more be said on the training of production engineers? The Institution has discussed it at length in Section meetings, in the 1954 Sir Alfred Herbert Paper by The Earl of Halsbury, in leading articles in the Journal of the Institution, after-dinner speeches, and the Graduates' Conference at Liverpool. Recently the Government's White Paper on "Technical Education" was published, in February, 1956.

The position today would appear to be this: there is a shortage of all technologists who are defined in the White Paper as those qualified to hold corporate membership of a professional institution, and who not only can apply the known technology, but may be expected "to push forward the boundaries of knowledge in his own field". Given such a shortage, how can we as a country, in view of the larger ratio of technologists per million population in competitive countries, provide more technologists without reducing standards?

The answer proposed in the White Paper for technologists which, of course, includes the production/industrial engineer, is to increase the opportunities for full-time and sandwich courses; to endorse the award (at degree level) to be given by the National Council for Technological Awards; to develop colleges of advanced technology, who should themselves increase the volume of advanced work; to encourage an increase in the supply and quality of technical teachers, and to encourage better technical library facilities. All these, of course, are very important and necessary if men with the ability and training are to be ready to face the increasing complexity of modern engineering.

But what of the content of the course? At the Graduates' Conference at Liverpool, many speakers thought that the basic purpose of education was to teach one to think. I do not intend to distinguish between education and training, but taking the fields of technology, it seems that acquisition of knowledge is the primary reason for study. The ability to apply that knowledge is a different and more difficult art.

Then, referring back to the definition of production or industrial engineering, it appears that as well as the basic technology required, the ability to use analytical techniques is most important. In considering problems, the production engineer should be taught to:-

analyse the problem and, after considering all aspects should synthesise possible solutions and from these, optimise for the available conditions and apply it. Then check back the result to the original analysis by comparative measurement; a mental feed-back, in fact.

The logical subjects to develop the analytical faculty are, I suggest, mathematics and economics, but, most likely, what one may call their industrial derivatives, namely, statistics and accounting, will prove the practical tools. These are not the "management subjects" required for Higher National Certificate endorsements and then forgotten; every field of production engineering will benefit from their study.

Education for production engineers needs to be broadened and, like all learning, should never stop.

(b) *Managers*

Anyone wishing to discover how to become a manager can find numerous books for reference on how to train for management. Many good authorities have distilled the principles of management which are given, in effect, in the definition above. But as the liberal or classical education of

old was the preparation for a full life, the study of the principles is merely a preparation for the maturing of experience of managing. To set objectives for one's own department or factory, to organise the means of achieving that objective, to motivate one's subordinates to attain the objective, to measure the achievements, to develop people ; this is *the* education for management.

But the benefits of study must not be belittled ; study both in management tools such as accounting, work study and economics to improve one's technology of management and study to develop other interests and a fuller life — to improve one's personal qualities (62% of a manager's requirements, according to Sir Walter Puckey).

The efficiency of a firm or of a country is a reflection of the ability of its management and virtually all the A.A.C.P. Productivity Reports commented on the relationship of good management practice to productivity. The report on " Education for Management " noted in particular the large number of graduate business schools and those offering first degrees in business and commerce.

" There is a quality in management, inspired by this climate of opinion, and stimulated by the American system of higher education in general and, in particular, by that part of it which is devoted to administrative studies ".

" The majority of efficient American firms are convinced of the practical value of these developments ".

In most large firms in Great Britain, the training of men assumed to be capable of management developed follows a similar pattern; namely, a period going through most activities of the business and part-time study of " management subjects ", followed by a position in his chosen field where he must find his own way. The periods in a department whilst under training are often enlivened by a project to be reported on at the end of one's stay. What benefit these projects are to the department is sometimes doubtful, but they do stimulate interest in the trainee.

In smaller firms, the opportunities for comparatively quick promotion are rare and there is less organised education for management, at least within the works. No doubt in the family business, the son who goes through the works is following the same cadetship as some trainee in a larger firm.

To sum up then, although there is no substitution for the experience of management, formal education for management could be greatly enlarged in Great Britain.

The Practice of the Professions

(a) *Production Engineering*

The organisation of the field of production/industrial engineering and therefore the practice of the profession, depends on the firm and the individual.

The size of the firm has obviously an important bearing on the organisation of the department and determines whether a large number of people in the field is employed, or whether one person is given the responsibility for the function alone. There are the two extremes, the one with many specialists and the other holding a position which entails responsibility for many activities.

In the U.S.A., from the many Productivity Reports, the field of production engineering, under various titles, covers a wide range of activities such as : preparatory planning, tools and fixtures, standardisation, production control, layout and materials handling, work study, financial incentives, suggestion schemes and safety precautions. In very few British large firms is such a varied programme maintained by one department; yet production engineering is the engineering of production and these activities above cover the preparation and achievement of plans, the improvement of doing things, and the consideration of the human beings who achieve these plans.

These activities are funnelled in to the routine work and the project work. In the day-to-day decisions, the engineer is judging the best of many choices, trying to obtain the best balance — in terms of operational research, he aims at optimisation of his resources. In project work, the engineer must make detailed analyses of alternative courses of action. The more information he has, the better his decision will be, for the intuitive decision on incomplete facts is not the best way to do things. In this country, the most important consideration will be the economic one, for most firms must make a profit to exist. "Will it pay "? is the criterion, and to find this out, close co-operation with the accountants is important.

Thus in the practice of production engineering the analytical approach, the exploration of alternative courses of action, the decision on the best (usually the most economical) way, all play their important part.

(b) *Management*

If it appears that I have underestimated the importance of the human side to production engineering, that is the one thing a manager must not do. His whole activity is influencing people, by example and leadership, to adhere to the plans he has prepared. Today the manager is influenced greatly by technical changes and thus he should appreciate the technology of his particular firm, but his important need is the ability to communicate his wishes, plans, enthusiasm and example to his subordinates and colleagues. One authority commented that the nearest approach to a purely vocational course for managers was a course in essay writing and poetry reading, introduced to " liberalise " a technical course.

A manager's fields of activity as a manager are covered in the definition above. He plans, controls, co-ordinates and motivates, i.e., leads and inspires. He may also file a tool (craftsman), pay the wages (wages clerk), follow-up some supplies (buyer), placate a customer (salesman), but this is not management as such. This Paper has tried to separate the management activities from the other necessary and urgent jobs often done by the manager; in his managerial sphere, the manager must analyse the information to develop his plans; he must communicate with his people; he must measure the achievement of his efforts and apply corrective action. The manager must have time to think.

Conclusions

The manager of today and the future needs to be a full man in the sense that he must be adequately prepared by general education, formal training and experience for the job he will do. He needs a scientific approach to and method in attacking problems. He needs wide knowledge to realise the implications, to the firm and to the community, of his actions. He needs the ability to build a team spirit in his dealings with colleagues and subordinates. He needs to measure his results.

I suggest that a professional production engineer has had the kind of experience necessary to meet these needs. He has had a scientific training; he should be using a scientific approach to problems; in his work he must deal with virtually the whole team within a firm; he measures the effectiveness of his work; he realises the impact further advances in production engineering technology towards automation will have in society.

With science as the "liberal arts" of the future, there will be no more talk of the scientific man as an inarticulate technician. The manager of the future must be articulate and technical.

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REVOLVING FUND FOR INDUSTRY

Three years ago a £700,000 Revolving Loan Fund for Industry was established, as a part of the Conditional Aid programme, for the purpose of increasing productive efficiency in industry. Since then, engineering, plastics, printing, textile and clothing firms are among those which have benefited through loans from the Fund.

The Fund provides short-term loans to enable suitable small manufacturers to buy up-to-date equipment and adopt modern techniques. It does not, however, provide funds for building work. In order to spread the benefits of the Fund as widely as possible, loans of more than £30,000 are not normally given, but no fixed maximum or minimum amounts have been laid down.

The Board of Trade state that increases in production and substantial savings in labour and material have been reported by firms who have been able to improve efficiency as a direct result of assistance from the Fund.

The major part of the Fund has been issued or is under negotiation, but as the Fund operates on a revolving basis the amount available for further loans is continually being supplemented as repayments are made and the Board of Trade are ready to consider further applications.

Further details of the Fund can be obtained from the Board of Trade, I.M.2 Division (Revolving Fund for Industry), Horse Guards Avenue, London, S.W.1. (Telephone Trafalgar 8855, Ext. 2382) or from the Regional Office.

THE FACTORIES ACTS—(*concluded from page* 283)

down of the equipment before danger develops, or alternatively, warning alarms can be brought into action. This aspect of safety requires to be kept to the fore, since there is the understandable tendency in design to concentrate on the production aspect and rather overlook the safety aspects.

The thought I would like to leave with you is the important part that you, as production engineers, can play in accident prevention over the whole of the industrial field, by having regard to safety in the design and manufacture of your products, whether it be merely a component, a machine, a piece of plant or some major work of engineering construction. At least, one can then rely on the tools supplied to industry being intrinsically safe instead of being potentially dangerous, and on there being less likelihood of any guard being interfered with, than would be the case if the guard had be added subsequent to manufacture. Certainly, on machinery more accidents happen because of the failure to maintain guards in position, than in the failure of the employer to provide them originally.

THE FACTORIES ACTS— HOW THEY AFFECT ENGINEERING ESTABLISHMENTS

by SIR GEORGE BARNETT,

H.M. Chief Inspector of Factories.

Presented to the N.W. Region of the Institution, in Manchester, 23rd April, 1956.

IT will be readily appreciated that in the time available it is not possible to cover the whole of the Factories Acts. What I propose to do, after a brief introduction, is to pick on some points which may be of particular interest.

Nowhere in the Factories Acts or Regulations is an engineering establishment defined. There is a reference to it, for example, in the term "Works of Engineering Construction", and it is mentioned in one or two odd places, but it is not defined. The term "engineering works" is presumed to be sufficiently well understood not to require definition and for the purpose of this talk, an exact definition or even an understanding of the term is unnecessary.

The general purposes of the Factories Acts are, of course, to ensure a certain standard of health, safety and welfare in certain industrial establishments, operations and processes and to exercise control over the employment of persons in such establishments, operations and processes.

Broadly speaking, the Act applies to any premises where articles are made, altered, repaired, ornamented, finished, cleaned, washed, broken up, demolished or adapted for sale where that is carried on by way of trade or for purposes of gain. Size is not a deciding factor; every place where such work is carried on is a factory if anyone is employed there. In fact, there are some 230,000 factories in this country and more than 82% actually employ less than 25.

All the provisions apply to what are generally known as factories, but certain of them are extended to building operations and works of engineering construction, i.e., defined types of civil engineering, as well as certain processes on docks with which we are not concerned here.

At the present time the Factories Act is comprised in the principal Act of 1937, which was amended to a small but important extent by the Act of 1948. In addition to the Act, there are, of course, a large number of orders and regulations.

It is rather characteristic of factory legislation in the U.K. that it has grown up in this piecemeal sort of way. In 1878 Viscount Cross, who was then Home Secretary, stated in the House of Commons that factory legislation was so complicated that he defied even a lawyer to understand or tell anybody where they stood so far as it was concerned. That was the year of the first consolidating Act. Since that date there have been various consolidating Acts.

First, let me mention very briefly the parts of the Acts that I am not going to develop here. They cover such requirements as hours of employment of women and young persons, holidays, overtime and medical examination of persons under 18 years of age. Then, of course, there are the various welfare requirements which were originally introduced in the Police Factories (Miscellaneous Provisions) Act in the 1914-18 War, dealing with such things as washing facilities, accommodation for clothing, drinking water, First Aid and matters of that sort. There are in addition the general health requirements as to ventilation, cleaning of toolrooms, overcrowding, maintenance of reasonable temperature and an adequate standard of good lighting, There is also a miscellaneous set of safety requirements dealing not only with the safety of workpeople in case of fire, but safety in conditions of floors, passages and stairways and a safe means of access to work and so on. These are the general provisions of the Factories Act, since they cover all sorts of premises. They must be quite general and, because of that, it is important that there should be an enabling clause in the Act to deal with any special hazardous processes which may be carried on in factories and to lay down specific precautions.

Section 60, which empowers the Minister to make regulations if he is satisfied that any manufacture,

machinery, plant, process, or description of manual labour, used in factories is of such a nature as to cause risk of bodily injury to persons employed in connection therewith, is a very important provision of the Act, and one which has resulted in the establishment of now well over 50 different codes of regulations. Some of them are quite extensive, running to 100 and even more clauses.

Having very briefly surveyed the general field, may I proceed to some of the points which I think will interest you most as engineers, and deal with them in a somewhat more definite and detailed manner.

Important Health Provisions

On the health side, for example, some of the most important provisions are the requirements in the Act designed to prevent the absorption into the body or inhalation of toxic or otherwise harmful materials, such as dust or fumes. In certain cases there are special codes of regulations dealing with this matter. Engineers will be familiar with the Grinding of Metals Regulations, and more recently the Iron and Steel Foundries Code, which specify particular methods whereby these hazards can be combated. But apart from these regulations, the Act contains certain requirements of a more general kind which have to be complied with wherever any process gives rise to such a danger.

Basically, the first line of approach should be an endeavour to replace the dangerous substances by harmless ones. This is not possible very often, of course, but failing that an endeavour should be made to prevent access by the worker by enclosing the material, the dust or the fume, and the plant in which it arises. Failing this, the next approach is to trap the dust or fume as near as possible to the point where it is created and, by means of suitable exhaust equipment, prevent its escape into the general atmosphere of the workroom.

If none of these methods is practicable, and dust or fume escapes into the atmosphere of the workroom, the general ventilation must be such as to prevent harmful pollution of the atmosphere. In such cases, it may be necessary for persons in such polluted atmospheres, especially those who are close to the source of dust or fume, to wear personal protective equipment. Finally, in certain cases it may be practicable to enclose the area where the dust is generated, although access by a limited number of workers may be necessary. Then the enclosure is fitted with exhaust draught in order to prevent escape of the dust or fume, and persons entering the enclosure must wear breathing apparatus which supplies them with clean air from the outside atmosphere.

From the engineering works point of view, the principal application of this will be the removal of dust in grinding, fettling and polishing processes, the cleaning of metal surfaces by shot or other abrasive blast, either as a finishing operation or in preparation for some other treatment, and the removal of the dust and fume, for example, in the preliminary foundry operations. These particular operations are subject to three special codes, the Grinding one already mentioned, the Blasting of Casting Regulations and the Iron and Steel Foundries Regulations. I mention these because they do exemplify the methods which I have just described. In the case of the Blasting Regulations, for example, the use of sand or other abrasives containing free silica is prohibited and the use of less harmful abrasives, i.e., steel shot or other types of shot, is thereby made obligatory. Secondly, under the Grinding Regulations, rumbling appliances, for example, have to be supplied with an exhaust which is applied internally, so that the dust cannot escape out into the air of the workroom. Thirdly, under both the Grinding Regulations and the Foundry Regulations, grinding and fettling equipment must be provided with exhaust equipment so arranged as to control the dust generated at the points of origin, to divert it into ducting and convey it into a collection plant outside the premises. There is also the requirement in the Iron and Steel Foundries Regulations as to the control of dust and fumes by good general ventilation. That particular code came into force in 1953.

We have had to fall back on that rather lower standard in certain cases because research work which is being carried out in connection, for example, with removal of dust at knockout and processes like that, has not yet been completed. I hope that before long the Industrial Research Association's work will be such that we shall have solved the problem of removal of the dust by exhaust methods or other practicable means, and shall not have to fall back on this less satisfactory system of having a high standard of general ventilation. From the health point of view, that is obviously not a satisfactory standard. It is difficult to control and there is bound to be a polluted atmosphere generally about the shop. Then, finally, under the Blasting Regulations, there is the example of the blasting chamber which the operator enters wearing a protective helmet supplied with air from the outer atmosphere.

The Safety Aspect

Dust and fume, and methods for their control, even in engineering works are matters of extreme importance. I now propose to look at some of the safety provisions of the Act and Regulations insofar as they affect the equipment of the engineering works.

Cranes form one piece of equipment common to most engineering works and at any rate there is the associated equipment which I suppose is in every engineering works — pulley blocks, winches, chains and other items of tackle. The requirements of the Act with regard to this type of plant are that all such plant must have been tested and examined before being taken into use and certificates of a test examination obtained. Then there have to be periodic examinations, not less frequently than six months in cases of certain equipment and twelve months in

others. The equipment must be of good construction, sound material, adequate strength and free from patent defects and, moreover, it must be properly maintained. Now those requirements are very specific and very definite, they are very important, and in law they are absolute. It is very important to remember that and it is important to remember, too, that 'maintained' is actually defined in the Act and means 'maintained in an efficient state in efficient working order and in good repair'.

In 1949, there was an accident case which went to the Courts for civil damages in connection with a hoist in Oldham, In that particular case, *Whitehead v. James Stott & Co.*, the accident had happened because the main shaft carrying the pulley at the top broke. Now, a visual examination would not have detected that particular flaw, but undoubtedly there was a flaw there. It might possibly have been discovered by an X-ray examination, but the occupiers of that factory were held to have been in breach of statutory duty under this absolute provision.

The same year there was a somewhat similar case which happened in Scotland, *Galashiels Gas Co. Ltd., v. O'Donnell or Millar.* In that case some coke was being taken up in a lift to a higher platform and the man got out with his barrow of coke and wheeled it away. When he came back he went, as he thought, to step into the cage of the hoist or on to the platform and this had disappeared. Actually it had gone up, and he fell down into the well and was killed. Now, according to the facts of that case, every effort was made by engineers to see if they could get this hoist to creep away again, in the way in which it had done on this particular occasion and they found that nothing whatever was wrong with the interlocking arrangement which should have operated. Nevertheless, in that case, too, it was held (and it went to the House of Lords) that there was a breach of these absolute requirements.

There are other important details to be taken into consideration. Of course, equipment must have the safe working load specified and this may be done by automatic indicator, or by affixing tables or notices so that the user can readily obtain this very vital information. Obviously, in deciding the safe working load of slings and similar gear, due account must be taken of various factors such as inclinations of sling legs when they are used. In the case of chains and other tackle made of metal whose tensile properties are affected by continuous usage, periodic heat treatment has to be carried out. Here I would like to emphasise the importance of seeing that the proper heat treatment is applied and that the work is done by someone who is fully competent. The various specifications of the British Standards Institution give useful advice, both on identification markings for the many different qualities of steel and on the appropriate heat treatment.

There is one other point I would like to emphasise particularly, concerning cranes. Far too many serious accidents happen because of the breach of this requirement: where a person is run over or crushed through being on or near the rail track of an overhead travelling crane. The Factories Act here makes it an offence for an overhead travelling crane to approach within 20 feet of a place where any person employed, working on, or near, the rail track would be liable to be struck by the crane. The cases of *Lotinga v. The North Eastern Marine Engineering Co.* and *Holmes v. Hadfield* emphasise the absolute requirements of this part of Section 24 of the Act. What it says is that effective measures have to be taken by warning the driver or otherwise to prevent the crane approaching within 20 feet of such a place. This requirement is obviously difficult to enforce because the human element cannot be completely eliminated, and yet, whatever measures are taken they must be effective; they must prevent that crane approaching within 20 feet and the two cases I have just mentioned show that if the crane does come within 20 feet, then there is an offence.

The requirements with regard to hoists and lifts were stepped up considerably in 1937, when the present requirements as to interlocking gates and examination and all the other details were brought in, and it is rather interesting, in this particular connection, to look at the figures of accidents just prior to the tightening up of the legal requirements. In 1936 there were 490 accidents on hoists and lifts in factories, 20 of which were fatal. In 1949, the accidents had come down to 115, five of which were fatal. This really decisive drop can be attributed very largely to the tightening up of the legal requirements.

With regard to steam boilers, the same type of requirements prevail — periodical examination by a competent person, test certificates and the question of good construction and maintenance, including all the details with regard to pressure gauges, safety valves, water gauges, etc., which go with a boiler. Since 1937, of course, similar provisions apply to what are known as steam receivers, and to air receivers which are in very common use in engineering works nowadays.

The Risk of Explosion

Another risk which I would like to emphasise as occurring in engineering works, is that which arises from the presence of dangerous vapours or fumes in confined spaces, which persons have to enter. They must have a manhole opening of a specified minimum size to facilitate entrance and egress. When a person enters such a place, he must wear breathing apparatus unless the place has been shown to be free of dangerous fumes and sufficient air is being admitted to ensure safety. Apart from the risk of gassing there also exists, in tanks or vessels which have contained an explosive or inflammable substance, a risk of explosion if heat is applied to the vessel. There are a surprising number of cases where a breach of this Section 28 occurs, where heat is applied by welding or brazing without proper precautions having been taken to free the vessel of inflammable vapour, where it has previously contained such liquids as petrol.

Clearly, I could spend the rest of my time on electrical equipment, but I must refrain and content myself with one or two salient points. The use of electricity in engineering works and in all factories, of course, is subject to the Electricity Regulations, which is quite an old code of Regulations and goes as far back as 1909. It is still operative, but with slight adjustments which were made in 1944. Regulation 1 is really all-embracing—"All apparatus and conductors shall be sufficient in size and power for the work they are called upon to do and so constructed, installed, protected, worked and maintained as to prevent danger so far as is reasonably practicable". One of the most important clauses is that dealing with the earthing of portable equipment. It is the use of portable equipment and loose cables that accounts for most of the electrical accidents in factories. The number of electrical accidents — the last figure was 730 — is not considerable when you reflect on the extent to which electricity is used in factories these days.

Mechanical Safety

Now, I would like to discuss a vital point, the question of mechanical safety, whereby the Act aims at the prevention of accidents on machinery by requiring in the case of prime movers that all moving parts shall be securely fenced and, in the case of transmission machinery and dangerous parts of other machinery, that secure fencing shall be provided unless they are of such construction or in such a position as to be as safe as they would be if securely fenced.

There has been a great deal of case law on this particular Section. I suppose I need only perhaps here mention two cases because I think they are particularly apt, and do more or less sum up the present position in law. The first one is the case of *Walker v. Bletchley Fletton Ltd.*, which was a case where a worker got his foot caught in certain gear wheels which were somewhat out of the way. In that case, Mr. Justice Du Parcq, as he was then, said that machinery was dangerous if it was a possible cause of injury to anyone acting as a human being would reasonably be expected to act, in circumstances which could reasonably be expected to occur. This dictum was, in fact, quoted in one of the most recent cases, that of *Frost v. John Summers & Co. Ltd.* That was the case where the worker injured his finger by touching an abrasive wheel which had the usual type of guard. He touched the part of the abrasive wheel which was necessarily exposed for the job that was being done. There, the House of Lords upheld the quite old judgment of Mr. Justice Salter in the case of *Davis v. Thomas Owen & Co. Ltd.*, where it was said that this section is absolute in requiring secure fencing of dangerous parts; it does not say that they need only be fenced if that is commercially practicable. What the Section really implies is that if a dangerous part of a machine cannot be fenced, then strictly speaking, it should not be used. As was pointed out in the House of Lords, there is power under the Section which I quoted with some emphasis just now, Section 60, for the Minister to modify the provisions of the Act. In the judgments it was suggested that the Minister should do that and as you probably all know now, the draft regulations for the fencing of abrasive wheels have been issued.

It was done, of course, in 1922 for woodworking machinery in order to deal with the fencing of circular saws and other types of machinery. It was done in 1931 for horizontal milling machines, and now similar procedure is being followed for abrasive wheels. The difficulty lies, of course, not so much with my department, which as you realise can deal with this matter administratively. The difficulty arises, nowadays, with the cases which go to the High Court for Civil Damages because if there is a breach of statutory duty then, of course, the worker is entitled to damages.

One other point I would like to make in connection with the fencing of machinery is one which is really covered by the regulations entitled "Operations of Unfenced Machinery Regulations". As engineers, you fully realise that there may be occasions when it is necessary, in the course of repair, to investigate and look into possible defects and for that purpose it may be necessary to run something which is normally required to be guarded, without its fence. These regulations permit this to be done under clearly defined conditions and safeguards. They deal with cases where it is necessary to carry out an examination of unfenced machinery in motion, or any lubrication or adjustment of such machinery which the examination has shown to be immediately necessary to carry out whilst it is in motion.

Now, the absolute standard of security for machinery laid down by statute does not necessarily mean that access to the particular part must at all times be prevented. This obviously would necessitate the provision of a fixed guard positively preventing access the whole time, whereas in practice secure fencing is considered to have been achieved if contact with the dangerous part is prevented whenever it is in motion. As you know, that can be done in various sorts of ways by guards which are automatic, or interlocked, or incorporate some trip action or some other feature which prevents the possibility of injury in consequence of some foreseeable act on the part of a person employed. There are many examples, of course, of such guards in use with which no doubt everybody here is quite familiar. If guards are successfully to serve their purpose, namely, the prevention of accidents, then obviously some rather special points must be watched. There are continual developments in this field and the application of electronics to industry, and the automatic handling of parts between progressive production processes, very often referred to as automation, are tending towards a re-appreciation of fencing techniques.

Provision for Possible Failure

However reassuring these new techniques may appear to be in regard to safety, and there is no

doubt that any method which achieves a reduction in the number of people exposed to risk must be encouraged, we must try and anticipate new sources of danger and meet them. Where safety depends on some automatic sequence, one must contemplate possible failure or breakdown of the arrangement and make provision so that any departure from the designed sequence results in the condition in which all parts are rendered safe under all circumstances.

In other words, the principle of failure to safety must invariably be applied.

So far, I have dealt with the Factories Act in relation to establishments commonly recognised as being factories, but I would like now for a moment or two to look at two other types — Building Operations and Works of Engineering Construction, because obviously these are matters which affect engineering establishments.

The requirements of the Factories Act itself apply to these operations only to a very limited extent, and so here is another case where the Minister can step in and make regulations to deal with them in detail. This, of course, has been done insofar as building operations are concerned and we have already published also two drafts of regulations dealing with Works of Engineering Construction. I have not time obviously to go into detail on these matters here — the Building Operation Regulations deal with safety, health and welfare and comprise some 100 clauses. The draft regulations dealing with Works of Engineering Construction originally comprised some 150 clauses.

Fencing of New Machinery

So far, I have rather directed my remarks to the occupier of the engineering establishment and touched on the sort of things he has to watch in health, safety and welfare of the workers he is employing. Now, these provisions obviously are extremely important, but I do want to lay some stress on the importance of one particular section which deals with the fencing of new machinery, which is particularly apt for an audience of this kind.

Many of you come from firms who obviously are making machinery for other people and there are obligations in the Act on the makers of such machinery if it is ultimately to be used in factories. They are limited, but they do require that all gearing of any sort, spur and pinion, friction, chain, sprocket, or whatever type of gearing it is, must be completely encased. Set screws and similar projections on spindles, pulley bosses, etc., must either be avoided altogether, or they must be securely fenced. There is power in that particular Section for the Minister to extend those provisions, but in factories generally so far, that has not been done. It is true that it has been done in connection with Building Operations and also it has been done in a rather special case in the Jute Regulations. In the latter, much of the jute processing machinery has a specification of the guards required and that is required to be done by the maker.

Production engineers are obviously interested in safety, and I would suggest that they can make a most important contribution to safety, not only to the advantage of their own establishments, but to the benefit of the industry in general. The suggestion is neither novel nor revolutionary, for already it has been given effect to, if not wholly, at least to a very considerable extent, by many makers of machinery and plant. It might be well expressed, I suppose, in the slogan : " Design for Safety ". I do feel that a great deal more might be done by incorporating safety at the design stage. Manchester is one of the centres of the machine tool industry and I would like certainly to congratulate that particular industry on the great strides they have taken along these particular lines. Excellent progress has been made during the last 30 years.

In this question of designing for safety, one must remember that safety is not entirely a matter of guarding. There is an opportunity for the designer to dispense with guards by making his machine such that it is safe without them. The number of accidents due to machinery represents only about 16%, less than one-sixth, of the total industrial accidents ; other accidents are due to plant in which lack of consideration for safety in design often plays an important part, while yet others are directly due to personal causes, although often there are a variety of factors influencing their occurrence. I would mention, in passing, the question of fatigue as being one of the indirect causes of accidents, and consideration for the convenience of the operative in machine and plant design can obviously play its part in the reduction of accidents.

As machines and plant become more and more complicated, particularly in the present tendency towards automatic processes, safety depends more and more upon the designer of the machinery or plant. It rests firmly with that designer to create conditions in which the operatives are not in danger. I have already referred to the principle of " failure to safety " and this is fundamentally a matter of design.

In this electronic age we are becoming more and more dependent on electrical equipment and devices and here, more than in any other field, is the principle of failure to safety essential. Back-up protection whereby the failure of two independent components is necessary before a dangerous situation can arise is another principle which can be applied with advantage. In such a case, however, some means of indicating failure of either component is advisable, so that the effectiveness of either component can be restored as soon as possible.

Provisions for Self-checking

In the electrical field also, self-checking and error correction provisions provide important conditions to safety. Ineffectiveness in a component can be self-checking by methods which will secure the shutting

(*concluded on page* 278)

CORRESPONDENCE

THE DELFT REPORT

From : **Mr. W. G. Ainslie,** M.I.Prod.E.

Referring to my comments on the Delft Conference, published in the March Journal, I wish to make it clear that these were not intended as a criticism of the Birmingham University Courses, which are at a Post-Graduate level. It was unfortunate that, unknown to me, my present position was stated in the introductory paragraph, since it has created the impression of inconsistency.

I fully support the Birmingham policy on Engineering Production; indeed, that is the reason why I sought to join the staff of the one British University which has so actively recognised this study for the past nine years, and which now has a flourishing Post-Graduate course.

The comments published were written in November, 1956, to the Education Committee of the Institution, prior to my joining the University staff, and as such cannot express University opinion.

THE SOUTHAMPTON CONFERENCE

From : **Mr. C. A. Burton,** *Sciaky Electric Welding Machines Ltd., Slough.*

I would like to take this opportunity of congratulating the Institution of Production Engineers for all the excellent work carried out in making the Fifth Annual Aircraft Production Conference such an outstanding success. This is the first time I have had an opportunity of attending this function and I am quite sure that this Conference will go from strength to strength in the years to come.

I should like to make one or two suggestions which I trust will be regarded as constructive criticism. Firstly, I would agree with a remark made by Mr. H. G. Gregory, that apart from a very short introductory preamble by each of the lecturers, the time available should be devoted entirely to discussion. I had a feeling that there were many present who had no opportunity of asking questions and, therefore, if more time were made available as suggested, it would be particularly helpful.

In my own particular field I was most interested to hear Mr. N. K. Gardner's Paper. This was, without doubt, a most praiseworthy effort which did not warrant Mr. Gardner's anti-climax statement when he intimated that many people may have listened to his lecture being critical of spot-welding, and would be going away still critical of spot-welding.

I am quite sure that the Handley Page Company have investigated every possible angle of this process and they have proved conclusively that spot and roll-spot welding, with the use of modern welding equipment and the introduction of adequate quality control procedures, can now be regarded as completely reliable.

Mr. S. G. Nash raised a query during the discussion when he asked what problems may be expected when welding stainless steel aircraft of the future. He queried the effect of the high pressures necessary for spot-welding stainless steel, and also asked if it might be possible to carry out assembly work with the use of portable machines. My own opinions of this future trend are that owing to the very low interfacial resistance of light alloy materials, and the fact that high welding currents, in some cases of the order of 150,000 ampères, have to be applied to the workpieces in conjunction with a variable electrode pressure cycle, it is most unlikely that portable spot-welding plant, with the aid of compressed air or hydraulically operated welding guns, will be developed.

It is quite a different matter, however, where stainless steel is concerned. This material requires very much lower welding currents than light alloys and a variable electrode pressure cycle is not required. The comparatively high constant pressures to be used can be very easily obtained by means of hydraulically-operated portable guns deriving their pressure from air-hydraulic intensifier units fitted to the machines. This obviates the necessity of fitting large air cylinders to the welding gun units and obviously reduces the bulk size and weight accordingly.

It is interesting to note that complete railway coaches are being manufactured by the Sorfame Company in Amadora, Portugal, the material being 17/7 stainless steel. Extensive use of portable gun welding plant is made, and providing that military aircraft of the future are designed with a view to employing resistance welding processes, then I can see no reason why similar schemes to those at present employed on commercial projects cannot be adopted.

From : **Mr. N. T. Burgess,** *Metallurgist, Aluminium Development Association.*

I was present at the Fifth Annual Conference on Aircraft Production, which I found most absorbing. As time for discussion was limited, I should like to contribute herewith, with the hope that the author concerned can offer some reply.

I refer to the Paper on "Contour Etching" by Mr. A. W. Sheppard. This Paper and the film were much appreciated and I should like to ask if the removal of quantities of metal by such a comparatively slow process results in less distortion, finally, than is evidenced in many cases when such components as he illustrates are machined by conventional procedures. Many members of the aircraft industry will be aware of the great difficulties in machining such items where, unless the aluminium alloy sheet is

specially prepared and produced, stresses may be present in the blank that will lead to troubles in machining. Does Mr. Sheppard feel that with contour etching distortion might be less?

Bearing in mind the diverse interests of the Company which Mr. Sheppard represents, I should like to ask whether he envisages applications for such sheet in fields other than the aircraft industry.

Finally, having seen the considerable difference in surface finish obtained with the different alloys with which Mr. Sheppard has worked, I should like to ask whether any work has been done on aluminium alloys other than the aircraft types, for example, NS3 (aluminium-1¼% Mn), NS5 (aluminium-3½% Mg) or the HS30 type.

From : **Mr. A. W. Sheppard,** Production Engineer, Saunders-Roe, Ltd.

In answer to Mr. Burgess' first query, after contour etching a slight distortion does take place due to stress release. However, because of the gradual and even removal of metal and the absence of local overheating, this distortion is negligible and in no way comparable with that which takes place after orthodox machining.

Although I know of no instances where contour etching is being used in fields other than the aircraft industry, I feel certain that there are great possibilities where weight saving is an important requirement; also in the limited manufacture of such items as the grid shown in my Paper.

With regard to Mr. Burgess' final question, we have not used the three alloys he mentions, but we have carried out work on alloys of similar composition which would almost certainly behave in a like manner. As can be seen from their chemical composition, apart from the absence of magnesium in NS.3, both the alloys NS.3 and NS.5 are similar to DTD 180c, and HS.30 and HS.10 are almost identical in specification.

NOTICE OF COUNCIL ELECTIONS, 1957/58

NOMINATIONS

(a) In accordance with Article 43, nominations are invited to fill ten vacancies for elected members to serve on Council for 1957/58 (i.e. eight Members and two Associate Members).

(b) Before candidates are nominated for election, their consent must be obtained.

(c) Candidates for election must be nominated in writing by three *Corporate Members of the Institution.

(d) In addition to nominations as in (c) each Section Committee may nominate one candidate.

(e) Nominations must reach the Secretary at 10 Chesterfield Street, London, W.1, not later than Wednesday 1st May, 1957.

(f) The members listed below are due to retire and are *not* eligible for re-election as 'elected members' until at least one year has elapsed.

Members :-

G. R. Blakely
A. E. Clifford
H. H. Dawson
A. F. Kelley
E. Levesley
R. N. Marland
H. Spencer Smith
H. Tomlinson

Associate Members :-

R. Hutcheson
†L. S. Pitteway

By Order of the Council
W. F. S. Woodford,
Secretary.
April, 1957.

†Mr. L. S. Pitteway, elected to Council as an Associate Member, will resign his seat as, since his election, he has been transferred to the grade of Member. He will be eligible for re-election as a Member.

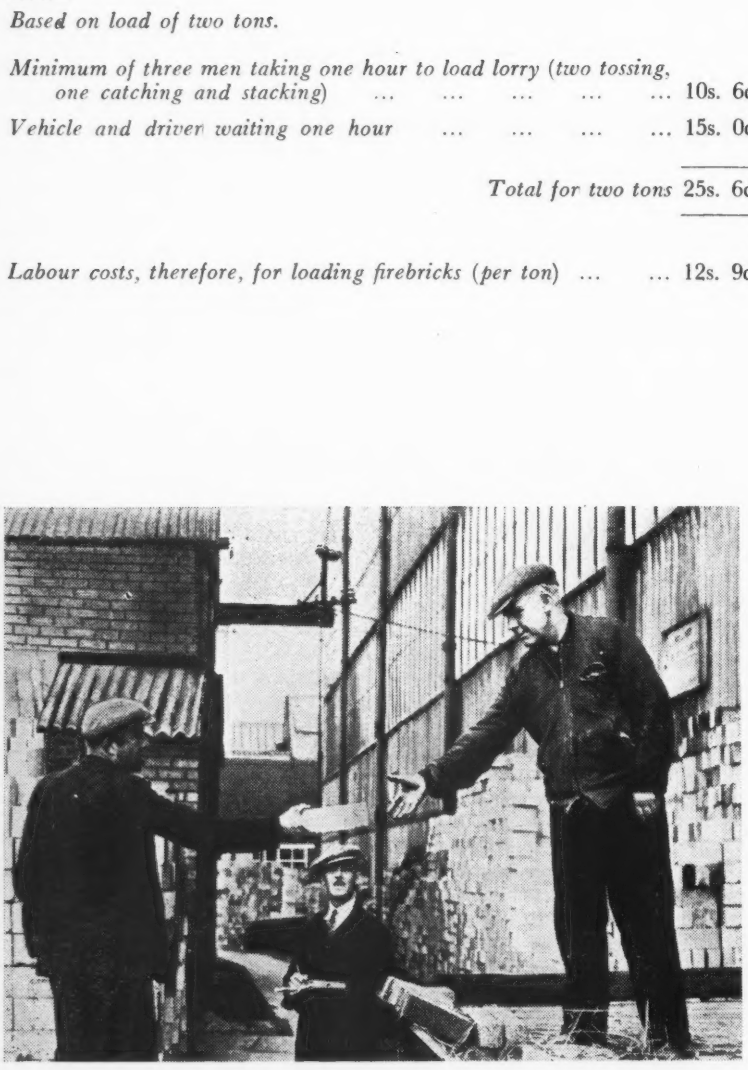
*Corporate members are :- Hon. Members, Members, Associate Members.

old method

Costs

Based on load of two tons.

Minimum of three men taking one hour to load lorry (two tossing, one catching and stacking)	10s. 6d.
Vehicle and driver waiting one hour	15s. 0d.
Total for two tons	25s. 6d.
Labour costs, therefore, for loading firebricks (per ton)	12s. 9d.



CASE STUDY No. 11

Handling of Refractories

Author: **A.M.I.Prod.E.**

An example of Handling Firebricks for Vehicle Loading.

The Company concerned is the parent of a large Group engaged in the design and manufacture of heat treatment and melting plant and associated ancillary equipment. It employs 1,000 people.

The Problem — loading of comparatively small quantities of firebricks some of which are very fragile, comprising a wide variety of shapes, sizes and qualities.

Whilst large quantities of firebricks required for extensive contracts are forwarded direct to site from manufacturers' works, stocks of various sizes and qualities are maintained by the Company for smaller contracts and repair work.

The Company's brickyard is somewhat remote from the main works, and had no lifting tackle of any kind. It comprises a large number of stacks of various sizes, shapes and qualities of firebricks, and comparatively small quantities have to be taken from these stacks to make up specific consignments.

Until recently, the procedure for despatching these consignments necessitated the road transport vehicle touring the brickyard, getting as close as possible to the appropriate stacks of firebricks, and loading by hand the various sizes, shapes and qualities required. This was an expensive procedure, involving considerable concentration of man power, slow turn round of vehicle and consequent delay in getting consignments away.

Whilst the permanent staff of the brickyard comprises two men, this procedure necessitated the transference of additional man power from elsewhere in the works, when vehicle loading was to be carried out.

An analysis of the procedure was

made and whilst complete palletisation and mechanisation could not be justified, the results showed that a compromise in that direction would be well worth while.

As a result of this investigation, a simple covered gantry was constructed, having two bays and housing a hand traversed electric hoist, as shown in the photograph. The width of the bays is sufficient to allow a standard road transport vehicle to pass through, one bay being used for this purpose, the other for storage of loaded pallets. On receipt of the requisition covering consignments of firebricks, pallets of suitable size for road vehicle use are preloaded, and stored in one bay of the gantry, in two stacks and two or three pallets high if necessary. The preloading of the pallets is carried out by the staff of two men well before the arrival of the transport vehicle, thus avoiding a heavier intermittent concentration of labour, which was previously necessary.

The transport vehicle on arrival drives into the clear bay and the appropriate preloaded pallet (or pallets) is immediately transferred to the vehicle, the turn-round time of which is reduced to a matter of minutes.

Summary of Savings and Advantages

1. Reduced cost of vehicle loading.
2. Reduced cost of transport charges.
3. Constant labour force in brickyard.
4. Quicker turn-round of vehicle.
5. Reduction in damage to firebricks when loading.
6. It is interesting to note that prior to the installation of the gantry, a mobile crane was used in conjunction with the pallets, but the saving that the gantry has brought about can well be appreciated, as it was previously necessary to requisition the mobile crane from the works, whenever its service was required, which involved a journey of approximately a quarter of a mile in each direction.

new method

Costs

Based on load of two tons.

Two men (stacking only) required for one hour to load one pallet (two tons)	7s. 0d.
Vehicle and driver waiting five minutes (at 15s. per hour) ...	1s. 3d.
Total for two-ton pallet	8s. 3d.
Labour costs, therefore, for loading firebricks on to pallets and thence on to vehicle (per ton)	4s. 1½d.
To this must be added pallet and hoist maintenance (per ton) ...	4d.
Total costs (per ton)	4s. 5½d.

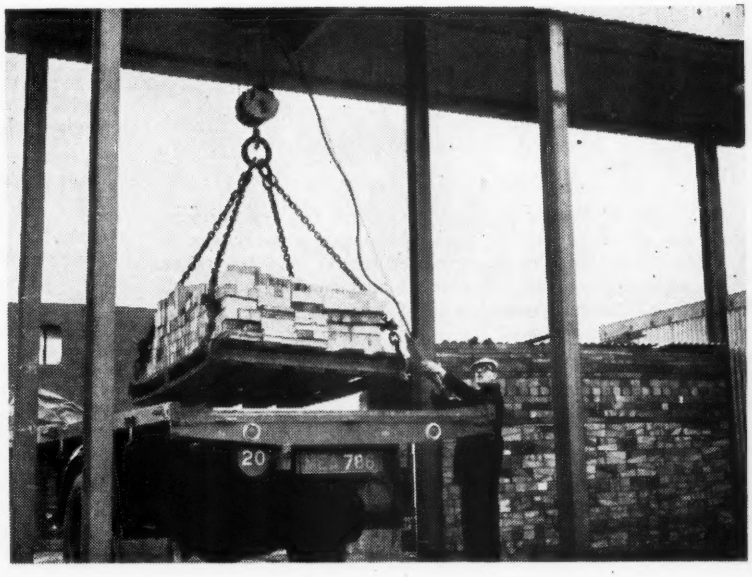
Therefore saving per ton — **8s. 3½d.**

Annual tonnage of firebricks despatched from the brickyard — **900 tons.**

Based on this figure the annual saving will be — **£373.**

Set against this is the cost of providing the gantry, second-hand hoist and pallets which totals — **£350.**

Therefore, the cost of the installation is recovered in the first year and subsequently a saving of **£373** per annum realised.



institution notes

Appointment of Education and Technical Officer

As recently announced by the Council, **Mr. F. W. Cooper,** B.Sc.(Eng.), M.I.Mech.E., M.I.Prod.E., Principal of the Chance Technical College, Smethwick, has been appointed Education and Technical Officer to the Institution.

Mr. Cooper will take up his appointment in London on 1st April, 1957.

Other Appointments

Mr. J. P. Ford, Member, has been appointed to the Board of Associated British Engineering Limited, as an Executive Director.

Mr. J. E. Oram, Member, has been appointed Managing Director of Wild-Barfield Electric Furnaces Limited, Watford. He was elected to the Board of the Company in 1933 and has been Director and General Manager for the last ten years.

Mr. R. J. Dawes, Associate Member, has now been appointed General Manager of Bush & Wilton, Bitton, Gloucester.

Mr. J. North, Associate Member, has relinquished his appointment as Works Manager with Bayley & Grimster Limited, Victoria, Australia, and has taken up the position of Technical Services Engineer with E. T. Brown Limited, also of Victoria.

Mr. P. H. Roberson, Associate Member, has been elected to the Board of Directors of his Company, Messrs. Penney & Porter Limited, Lincoln, as Works Director.

Mr. D. Treasurer, Associate Member, has relinquished his appointment with Messrs. Jones, Tate & Co. Ltd., and is returning to Messrs. Dewrance & Co. Ltd., as a Production Controller.

Mr. A. Rainbird, Graduate, has taken up an appointment as Engineer with the Manufacturing Methods Engineering Department of the Communications Equipment Division of the Northern Electric Company of Montreal, Canada.

Obituary

Members in the Midlands Region of the Institution will be sorry to learn of the death of **Mr. Tom Houghton,** Associate Member, Technical Officer (Training), with Joseph Lucas & Co. He had been Social Secretary of the Birmingham Section for over 16 years, and did sterling work in fostering the interest of the younger members in Institution activities.

He was a man who was well-liked and respected throughout the Midlands, and will be greatly missed by his many friends and colleagues.

President's Visit to S. Essex

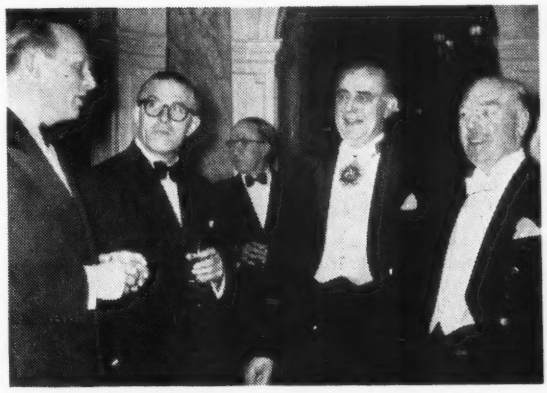
At the January meeting of the South Essex Section, the chair was taken by the President of the Institution, Mr. E. W. Hancock, M.B.E., and the occasion attracted the highest attendance so far recorded for the Section. The speaker was Mr. D. T. N. Williamson, who gave a first-class Paper on "Electronic Computer Control of Machine Tools."

Prior to the meeting, the President was entertained to dinner by the Section, and among the guests were the Mayor of Chelmsford; Mr. C. E. Preston, Principal, Mid-Essex Technical College; Mr. R. Telford, Chairman, S.E. Region; Mr. A. K. Brown, M.I.Prod.E., Works Director, Hoffman Manufacturing Co. Ltd.; and Mr. R. R. Kenderdine, M.I.Prod.E., Works Director, Crompton Parkinson, Ltd.

N.W. Regional Dinner

The Third North Western Regional Dinner was held at the Midland Hotel, Manchester, on Friday, 8th February last, and was attended by nearly 150 members and guests. The Principal Guests were The Lord Mayor of Manchester; Mr. H. G. Gregory, Chairman of Council; Dr. B. V. Bowden, Principal, Manchester College of Science and Technology; and Mr. W. F. S. Woodford, Institution Secretary.

It was unanimously agreed by those present that this year's function was the most successful so far held in the North-West, and thanks and appreciation for his part in organising the function were expressed to Mr. J. G. McLean, of the Manchester Section.



Left to Right: **Mr. Woodford; Mr. A. Barton; Mr. S. Brown; The Lord Mayor of Manchester (Councillor Harry Sharp, J.P.); and Mr. J. H. Winskill, N.W. Regional Chairman.**

Hazleton Memorial Library

REVIEWS & ADDITIONS

Members are reminded that copies of the Library Catalogue may be obtained from the Librarian, price 2/6d., plus 4d. postage (price to non-members, 10/-, plus 4d. postage).

"Information Processing Equipment" edited by H. P. Doss. *New York, Reinhold,* 1955. 270 *pages.*

The Papers in this book were originally prepared for a symposium on the "Equipment for the Preparation, Reproduction and Utilisation of Technical Information", organised in 1953 by the American Chemical Society, and this excellently describes its contents. There are chapters on special typing, stencilling and hectographing; lenseless copying with sensitised papers; photography in the laboratory; microcopying; dry photographic copying; letterpress and offset printing; authors' guide to effective slides; audio methods for handling data; storing and finding technical information with punched cards; and numerical data handling machines.

For the most part the book is concerned with equipment, and it is not likely to be of direct interest to the practical engineer. The guide to the preparation of lantern slides could, however, be studied with profit by all who prepare lectures and Papers, and in certain of the chapters (in particular, "Photography in the Laboratory" and "Audio Methods of Handling Data") imaginative uses for the equipment are indicated, which could be stimulating, particularly to the research worker.

The main use of the book, however, would be as a reference book for those concerned with the physical handling of information and data; to these it would be valuable, though its usefulness in this country is limited by the fact that without exception all the equipment described is American. However, similar equipment is, for the most part, available in this country. The book is excellently illustrated and there are copious bibliographies in each chapter. M.L.A.

"Factory Electrification" by F. T. Bartho. *London, Macdonald and Co. (Publishers),* 398 *pages.* 35s.

This book deals essentially with the factors affecting the selection, operation and maintenance of the plant and equipment needed to distribute electricity in a factory as well as of the motors needed to power the machines. As such, it is directed more to the electrical engineer than to the production engineer. This is particularly so, since the specialist electrical equipment which may influence production such as welding plants, lighting, furnaces, heaters and the like has been deliberately omitted. The discussion on a.c. and d.c. electric motors and their control gear is, however, particularly full and in the 235 pages devoted to this subject, data is given to quick designers in the choice of specific types for any given subject. M.J.S.

"Electronic Computers and Management Control" by Zmetsky, George and Kircher, Paul. *New York and London, McGraw-Hill,* 1956. 296 *pages.* $5 (37s. 6d.).

Management executives and others concerned with the operation of offices, involved in the processing of information should read this book. It is a good account of developments in the United States of America. The integrated system including the computer is placed in its proper perspective; and reference is made to a number of actual applications in different organisations and the problems. The safeguards which are necessary are well brought out, and proper emphasis is laid on the need for a well planned approach to the training of people, to the changing of their attitudes, and to the unifying of systems. The authors explain in sufficient detail the operation of the computer and enlarge

on possible applications. They describe the administrative problems which may be encountered and enlarge on the modern concept of managerial control in relation to the use of the computer. The appendices are of value as they give information about current electronic data processing equipment, there is a useful bibliography, and a satisfying layout of the works of a computer. Finally, there is an interesting mathematical model for integrated data systems. The book is well written and is interesting to read.

A.A.J.

ADDITIONS

" The Challenge of Automation " : Papers delivered at the National Conference on Automation, Washington, 1955. *Washington, Public Affairs Press,* 1955. 77 *pages.*
The Conference was held under the auspices of the Committee on Economic Policy of the Congress of Industrial Organisations. There is little technical content in the Papers, most of which deal with labour problems; or in a general way with technical considerations.

Connell, Robert S. **" Tool and Cutter Grinding."** *Brighton, Machinery Publishing Co.,* 1956. 158 *pages. Illustrated. Diagrams.* 18s. 6d. (Machinery's Standard Reference Series).

Dipple, Raymond. **" Process Planning."** *Richmond, Association of Engineering and Shipbuilding Draughtsmen,* 1956. 119 *pages. Illustrated. Diagrams.* 4s. (Association of Engineers and Shipbuilding Draughtsmen Session, 1955/56). The author describes the techniques of process planning, with special reference to machine shop work.

Fincham, W. H. A. **" Optics ".** 6th edition. *London, Hatton Press,* 1951. 426 *pages. Illustrated. Diagrams.* A textbook for students of applied optics, up to the stage when he begins to specialise in such subjects as opthalmic optics and optical instruments. Also suitable as a textbook for the intermediate examination in science of universities.

Foundry Trade Equipment and Supplies Association, London. **" British Foundry Plant and Supplies."** 2nd edition. *London, the Association,* 1956. 32 *pages.*

Geigher, P. H. **" Noise Reduction Manual."** Originally prepared under the auspices of Office of Naval Research. *Ann Arbor, Mich., Enginering Research Institute, University of Michigan; University of Michigan Press,* 1955. 167 *pages. Diagrams.* Devoted to noise problems from a . . . practical viewpoint.

Inter-University Contact for Management Education, Delft. **" Industrial Engineering and Management at University Level in European Countries " :** Report of the E.P.A. — I.U.C. Survey, 1954. Volume 1. Project No. 277 of the European Productivity Agency (E.P.A.). Delft, Inter-University Contact for Management Education, 1955. 27 pages + 35 pages duplicated.

Johnson, Ellis A. **"The Application of Operations Research to Industry " :** a speech delivered at the Fifth Annual Industrial Engineering Institute, University of California . . . 1953. *Chevy Chase, Maryland, Operations Research Office, Johns Hopkins University,* 1955. 61 *pages. Diagrams.* $1.75.

Knowles, Raymond S. B. **" The Secretary's Guide to the Law of Town and Country Planning ",** edited by F. H. J. Wileman. *London, Corporation of Secretaries,* 1956. 96 *pages.*

Laing (John) and Son Ltd., London. **" Teamwork " :** the story of John Laing and Son Ltd. *London, the Company,* 1950. 108 *pages. Illustrated.* The story of the civil engineering and contracting firm begins at the end of the 18th century. The greater part of the book is devoted to the activities of the firm under John W. Laing in the present century.

Larkin, Edgar J. **" The Elements of Workshop Training " :** a textbook for works' apprentices. 2nd edition. *London, Pitman,* 1947. 260 *pages. Illustrated. Diagrams.*

McCadams, William H. **"Heat Transmission."** 3rd edition. *London, McGraw-Hill,* 1954. 532 *pages. Illustrated. Diagrams.* 61s. Designed to serve both as a text for students and as a reference for practising engineers.

Mechanical Engineering Research Board. **" Report of the Mechanical Engineering Research Board (Department of Scientific and Industrial Research), with the Report of the Director of Mechanical Engineering Research for the Year 1955."** *London, H.M.S.O.,* 1956. 72 *pages. Illustrated.* 4s.

Mond Nickel Company Ltd., London. **" The Heating of Nickel."** *London, the Company,* 195-. 47 *pages. Illustrated. Diagrams.*

Monday, C. **" Centre Lathe Work."** *Brighton, Machinery Publishing Co. Ltd.,* 1956. 160 *pages. Diagrams.* 18s. 6d. (Machinery's Standard Reference Series.) Contents:- The centre lathe: its construction and types ; lathe tools ; external cylindrical work ; drilling, boring and reaming on the lathe ; taper and elliptical turning ; screwcutting ; miscellaneous uses of the centre lathe.

National Physical Laboratory, Teddington, Middlesex. **" Noise Measurement Techniques."** *London, H.M.S.O.,* 1955. 40 *pages. Illustrated. Diagrams.* (Notes on Applied Science No. 10.) 2s. Intended to be a guide to the choice of methods and techniques suitable for the measurement of the physical characteristics of noise in varying circumstances. Describes the equipment used and its operation.

Northcott, C. H. **" Personnel Management : Principles and Practice."** 3rd edition. *London, Pitman,* 1955. 427 *pages.* 30s. Previous editions of this standard textbook were called " Personnel Management: its Scope and Practice ". This edition has been considerably revised. It covers all aspects of personnel management, from industrial relations to job evaluation.

Office Belge Pour l'Accroisement de la Productivité, Brussels. **" Les Principaux Facteurs de Productivité : Mission Belge Aux Etats-Unis, 1952."** *Brussels, the Office,* 1955. 162 *pages.* (Enquete en vue de la Accroisement de la Productivité.) The Belgian Mission to the United States in 1952, visited a wide range of educational and industrial organisations. Its report on " the factors which effect productivity" comprises a survey of education, human relations, and of social conditions; and of the structure and organisation of industrial enterprises.

Organisation for European Economic So-operation, Paris. **" Buyer's Guide to European Machinery."** *Paris, the Organisation,* 1955. 46 *pages.* A classified list to Engineering Trade Associations in Western Europe. In English and French.

Plant Maintenance and Engineering Conference, Chicago, 1955. **" Techniques of Plant Maintenance and Engineering 1955."** Proceedings of the technical sessions held concurrently with the Sixth National Plant Maintenance and Engineering Show, Chicago, January, 1955. *New York, Plant Maintenance Show, Inc.,* 1955. 218 *pages. Diagrams.*

Porter, Harold W. and others. **" Machine Shop Operations and Set Ups"** by Harold W. Porter, Charles W. Lawshe and Orville D. Lascoe. *Chicago, American Technical Society,* 1954. 397 *pages. Illustrated. Diagrams.* An elementary well illustrated book for machine operators.

Powell, C. F. and others. **" Vapor-Plating : the Formation of Coatings by Vapor-Deposition Techniques "** by C. F. Powell, I. E. Campbell and B. W. Gonser. Sponsored by the Electrochemical Society Inc., New York. *New York, Wiley ; London, Chapman & Hall,* 1955. 158 *pages.* The term " Vapor-Plating " as here used denotes the chemical processes such as hydrogen

reduction or thermal decomposition of metal halides at heated surfaces. The techniques employed in vapor-plating are described, and the conditions requires for the deposition of pure metals, carbides, nitrides, borides, silicides and oxides from gaseous mixtures of their vaporised components are discussed.

Reuther, Walter and Davis, D. J. **" Automation in the American Automobile Industry " :** reprints of articles (from) *Labour News from the U.S.* (Volume 7, Nos. 1, 2 and 3) ; and a glossary of automation terms compiled by the U.A.W. *London, United States Information Service, Labor Information Office,* 1956?. 29 *pages duplicated.* The Papers by Reuther (President, Union of Automobile Workers are on " Labour Relations " ; the one by Davis (Vice-President, Ford Motor Co.) on " Technological Developments at Ford's ".

Riddle, Johnny. **" Ball Bearing Maintenance."** *Norman, University of Oklahoma Press,* 1955. 170 *pages. Illustrated. Diagrams.* A survey of design features and maintenance principles which govern performance and service life with a . . . study of service failures.

" Symposium on Electronics and Automatic Production ", jointly sponsored by National Industrial Conference Board Inc., New York, and Stanford Research Institute, Menlo Park, California, San Francisco, 1955. *Looseleafe. Photographs. Diagrams.* Contents:- Automation — what is it ? ; opportunities and problems in various industries (automotive, steel, chemical, electronics) ; automatic handling of business data ; automatic production and the small business man.

Thompson, R. N. **" Welding Dictionary : French - German - Spanish-English ",** compiled and edited by R. N. Thompson and G. Haim. *London, Iliffe for Welding,* 1950. 234 *pages.* 21s.

Urwick Orr and Partners Ltd., London. **" Electronics and Everyman " :** developments in the field of electronic computing. *London, the Company,* 1955. 92 *pages.*

Advisory Council on Scientific Policy. **" Report on the Recruitment of Scientists and Engineers by the Engineering Industry "** by the Committee on Scientific Manpower. Professor S. Zuckerman, Chairman. Lord President of the Council. *London, H.M.S.O.,* 1955. 31 *pages.* 1s. 3d.

American Society for Metals, Cleveland, Ohio. **" Metals Handbook."** 1955 Supplement. *Cleveland, the Society,* 1955. 208 *pages.* 50s.

American Society of Mechanical Engineers, New York. **" Engineering Tables ",** edited by Jesse Huckert. *New York, the Society,* 1956. 16 *parts. Diagrams. Tables.* 90s.

Barton, H. K. **" The Diecasting Process."** *London, Odhams Press,* 1956?. 224 *pages. Illustrated. Diagrams.* 21s.

Barwell, F. T. **" The Lubrication of Bearings."** *London, Butterworth's Scientific Publications,* 1956. 292 *pages. Illustrated. Diagrams.*
" . . . an attempt to select the more significant of the researches which have been published in the last 50 years and to present them in a form which will not only enable research workers to appreciate the essential achievements of past workers as a basis for further effort, but which will enable practising engineers to have in compact form such data as will enable them to design bearings and similar components of the kinematic chain in accordance with modern knowledge . . . ".

Barwell, F. T. **" Plastics Engineering."** *London, Cleaver-Hume Press,* 1956. 458 *pages.* Reprint of Chapter XIX of " Modern Workshop Technology ". Part 1, 2nd edition. Edited by Wright-Baker.

Black, Paul H. **" Machine Design."** *New York, McGraw-Hill,* 1955. 471 *pages. Illustrated. Diagrams.* 56s. 6d.
" Intended to serve as a textbook in general machine design and as a reference book in mechanical design offices. It is assumed that the reader has a knowledge of mechanics, strength of materials, kinematics, mechanical processes and engineering materials."

British Productivity Council, London. **" Iron and Steel."** *London, the Council,* 1956. 48 *pages. Illustrated.* (Productivity Review.) 2s. 6d.

British Iron and Steel Research Association, London — Plant Engineering Division. Eighth conference : a summary of proceedings . . . (London . . . 1952). **" Engineering Maintenance."** *London, the Association,* 1952. 24 *pages.* 5s.

Brooks, Collin. **" An Educational Venture : History of Woolwich Polytechnic."** *London, Woolwich Polytechnic,* 1955. 149 *pages. Portraits. Illustrations.*

Chief Inspector of Factories. **" Annual Report, 1955."** *London, H.M.S.O.,* 1956. 275 *pages. Illustrations.* 9s. Cmnd 8.

Copper Development Association, Radlett, Herts. **" Copper for Busbars."** Sixth improved, revised and enlarged. *Radlett, the Association,* 1956. 176 *pages. Illustrated. Diagrams.*

Custer, James R. (editor). **" Applied Automation " : a group of significant articles from the pages of *Automotive Industries* showing the application of modern automation techniques.** *Philadelphia, Penn., Chilton Co. for* **Automotive Industries** *; London, Bailey Bros. and Swinfen,* 1956. 236 *pages. Illustrated. Diagrams.* 48s.

Dooher, M. Joseph and Marquis, Vivienne (editors). **" Effective Communication on the Job : a Guide to Employee Communication for Supervisors and Executives."** *New York, American Management Association ; London, Bailey Bros. and Swinfen,* 1956. 294 *pages. Diagrams.* 44s.
The art of " communication " — of saying what you mean, has occupied the attention of philosophers and philologists for centuries, and has recently become a branch of that eclectic subject " Scientific Management ". This book deals with communication " up " and " down " and includes chapters on interviewing conference leading, and order giving.

Eusec Conference on Engineering Education, London, 1953. **Conference of representatives from Engineering Societies of Western Europe and the United States of America . . . . Eusec Conference on Engineering Education.** *London, Institution of Civil Engineers for the Organising Committee of the Institution of Civil Engineers, Institution of Mechanical Engineers, and the Institution of Electrical Engineers,* 1953 171 *pages.*

Fuller, Dudley D. **" Theory and Practice of Lubrication for Engineers."** *New York, Wiley ; London, Chapman and Hall,* 1956. 432 *pages. Illustrated. Diagrams.*
Attempts to present the theory of lubrication in " the most understandable and usable form " and to " demonstrate the usefulness of lubrication analysis in solving engineering problems ". The hydrodynamic and hydrostatic theories have been developed from first principles.

Grover, J. J. and others. **" Fatigue of Metals and Structures "** by H. J. Grover, S. A. Gordon and R. L. Jackson. (Batelle Memorial Institute.) *London, Thames and Hudson,* 1956. 401 *pages. Diagrams.*
Summarises most of the current information about metals fatigue. Directed to the designer or engineer with some knowledge but limited experience of fatigue problems. The bibliographies are good, but refer mostly to American publications.

Gentzel, Herman P. **" Reference Manual of German Machine Tools."** *Coburg, Karl Ihl and Co.,* 1956. 369 *pages. Illustrated.* 47s. 6d.
A guide with detailed descriptions of German machine tools. Divided by kind of machine, with a manufacturer's index. Conversion tables. In English.

Hardy, H. W. **"Planetary Gearing : Design and Efficiency."** *Brighton, Machinery Publishing Co.,* 1956. 59 *pages. Diagrams.* 4s. 6d. (Yellow Back Series, No. 37.)
An account of planetary gearing based on the equivalent-lever and tabular methods with a number of fully worked out examples and methods of calculating the efficiency of single and multiple units.

Heine, Richard W. and Rosenthal, Philip C. **"Principles of Metal Casting."** *New York, McGraw-Hill,* 1955. 639 *pages. Illustrated. Diagrams.* 56s. 6d.
Intended as a textbook for first-year college students; for metallurgical engineering students. Only certain chapters are assigned to the latter and there is a certain amount of duplication for the sake of emphasis.

"Hopper Feeds as an Aid to Automation: Design and Application of Automatic Feed Devices in the Machine Shop." *Brighton, Machinery Publishing Co.,* 1956. 68 *pages. Illustrated. Diagrams.* 4s. 6d. (Yellow Back Series, No. 39.)
Discusses the basic principles of the various types of hopper feeds, and the design of hoppers for some special applications. The intermediate feed mechanisms associated with such hoppers are described.

Jay, Kenneth. **"Calder Hall": the story of Britain's first atomic power station.** *London, Methuen,* 1956. 88 *pages. Diagrams.* 5s.
A popular description of Calder Hall.

"Machine Tool Automation by Electronic Control." Automatic repetitive operation and positioning by tape, computer and other related methods. *Brighton, Machinery Publishing Co.,* 1956. 88 *pages. Diagrams.* 4s. 6d. (Yellow Back Series, No. 38.)
Describes systems of machine tool control and employ electronics, especially those based on the electronic computer, and on punched and magnetic tape. Systems of precision automatic positioning of machine tool members by electronics are also dealt with.

Organisation for European Economic Co-operation, Paris. **"Internal Transport in Iron and Steel Works."** *Paris, European Productivity Agency of the O.E.E.C.,* 1956. 216 *pages.* 59 *photographs.* 7s.
Report of a mission undertaken for the European Productivity Agency by the Chambre Syndicale de la Sidergurgie Francaise. The mission studied methods used in the iron and steel works of several European countries.

Organisation for European Economic Co-operation, Paris. **"Titanium, Zirconium and Some Other Elements of Growing Importance."** *Paris, European Productivity Agency of the O.E.E.C.,* 1956. 123 *pages. Illustrated. Diagrams.* 10s.
Report of a mission which visited the U.S.A. Its main task was to study the production and refining of titanium, zirconium and beryllium. Its second task was to study the semi-conductor metals and compounds, and metals for high-temperature use.

"Oxford History of Technology, Vol. 2 — The Mediterranean Civilisations and the Middle Ages, c. 700 B.C. to A.D. 1500. *Oxford, Clarendon Press,* 1956. 802 *pages. Illustrated.* 44 *plates.*
The second of the proposed five volumes of the "Oxford History". Vol. 1 dealt with the earliest times to the fall of the ancient empires (c. 500 B.C.), and the last will deal with the age of steel (1850 - 1900).

Pyke, Magnus. **"Automation: its Purpose and Future."** *London, Hutchinson's Scientific and Technical Publications,* 1956. 191 *pages. Illustrated. Diagrams.* 16s.
The author describes the basic principles of "automation" with particular reference to the computer, and goes on to describe their applications in various industries. He discusses the factors likely to effect the speed with which "automation" is introduced in different countries.

Schlesinger, G. **"Die Werkzeugmaschinen: Grundlagen, Berechnung und Konstruktion."** *Berlin, Springer,* 1936. 2 volumes. *Illustrated. Diagrams. Plates.*
This classic work on machine tools is now a bookseller's rarity. The Library is fortunate to possess a copy of the first edition.

American Society of Mechanical Engineers, New York. **"Engineering Tables",** edited by Jesse Huckert. Sponsored by the Metals Engineering Handbook Board of the American Society of Mechanical Engineers. *New York, etc., McGraw-Hill,* 1956. 15 *parts. Tables. Diagrams.* 90s.
The aim of the handbook is to provide tables which are often wanted by engineers, but which are not generally found in handbooks. Thus "methods of finding the loads on ball bearings are included; the loads that ball bearings can safely carry are not. Data upon bars and tubes suitable for revoking into gears, levers, shafts or screws are included; the sizes of rolled sections as used in structures are not". In general a source is given for each table, most usually the A.S.A. There is a useful list of U.S.A. standards and specifications.

American Society for Metals, Cleveland, Ohio. **"Metals Handbook: 1955 Supplement."** Prepared under the direction of the Metals Handbook Committee. Taylor Lyman, editor. *Cleveland, American Society for Metals,* 1955. 203 *pages. Illustrated. Diagrams.*
This is the second supplement to the 1948 Metals Handbook. The work is divided into four sections: Metals and applications; Design and application; Processing and fabrication; Testing and inspection.

Cole, E. B. **"The Theory of Vibrations for Engineers."** 3rd edition. *London, Crosby Lockwood,* 1957. 362 *pages. Diagrams.* 30s.
This textbook is intended to bridge the gap between the accounts of elementary principles which appear in most textbooks and the many advanced Papers which have appeared in recent years, which, because of the high degree of mathematical attainment necessary for their comprehension, cannot be appreciated by the average engineer and student. In this edition the scope of the work has been extended either in the text or in the appendices, and the number of worked-out examples has been added to.

Corporation of Secretaries, London. **"The Secretary's Guide to the Restrictive Trade Practices Act, 1956",** by the Right Honourable the Lord Meston, Barrister-at-Law. *London, Corporation of Secretaries,* 1956. 96 *pages.*
A well indexed and well planned guide.

Institute of Welding, London. **"Handbook of Welding Design."** Compiled under the auspices of a special committee of the Institute of Welding. General editor, C. Rowland Harman. Vol. 1. *London, Pitman, for the Institute of Welding,* 1956. 305 *pages. Tables. Diagrams.* 45s.
This handbook supersedes the Institute's "Handbook for Welded Structural Steelwork", which was last revised in 1946. "The handbook is confined to information relevant to the design of products fabricated in mild or low-alloy steels by the metal arc welding process. Wherever possible the information is based upon the relevant British Standard or other recognised specification . . . The workshop aspects of welding are referred to only where the designer can be given guidance to avoid fabrication difficulties by careful choice of design and details. The purpose of this first volume is to provide the designer of a welded assembly with the fundamental data necessary to design a product that is both economical to make and of the required standard of quality." The principles of the arc welding process are described, and information given about the thermal and metallurgical effects of welding, the use of pre- and post-heating methods, and the considerations involved when the automatic arc welding processes are used. The materials generally available are described and guidance given on their use. As these materials are available in a number of rolled shapes, data is given on the properties of British rolled sections, together with tables showing the properties of composite built-up sections assembled by welding. There is a summary of the British classification of mild-steel electrodes, and information about their applications. The design and application of welded joints and structures are fully dealt with in three chapters. Factors influencing welding costs are discussed in the final chapter, and a short appendix gives a summary of the maximum dimensions and weight limits laid down by regulations for the transport of goods by rail and road. Volumes 2 and 3 will deal with the application of principles and data given in Volume 1.

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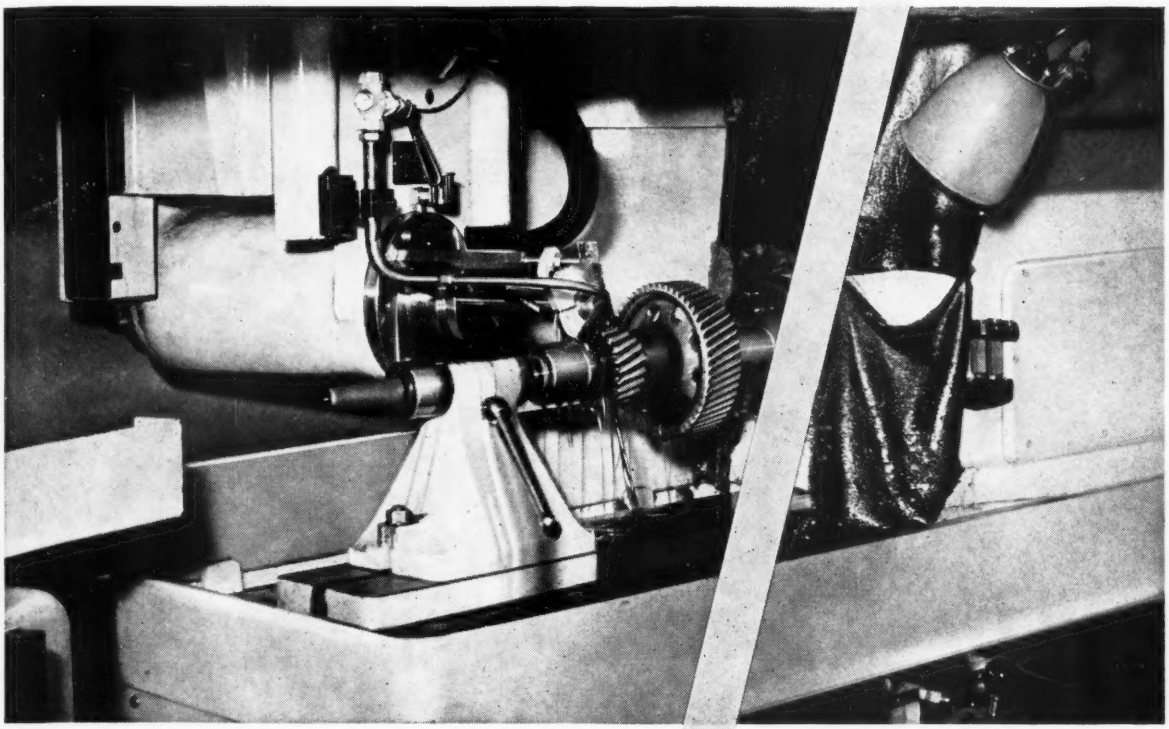


Orcutt H.K.N. External Helical Gear Grinding machine grinding low-speed teeth of Dart 510 propeller turbine layshaft at Derby with "Ilocut"

"Ilocut" is Wakefield-Dick's best known range of neat cutting oils. Its high quality never varies—and it is specified by a number of this country's leading production engineers. Rolls-Royce Ltd. use "Ilocut" and many other of our production oils in their Aero Engine Division at Derby in addition to their Crewe, Barnoldswick and Glasgow works.

INDUSTRIAL WAKEFIELD-DICK LUBRICANTS

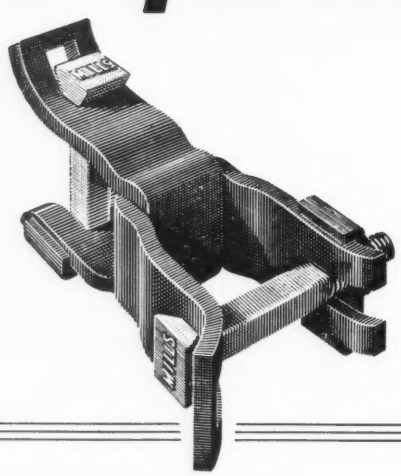
WAKEFIELD-DICK INDUSTRIAL OILS LTD., 67 GROSVENOR STREET, LONDON, W.1

IF YOU WANT THE BEST
OF EVERYTHING TO DO WITH
TUBULAR SCAFFOLDING SERVICE

say

MILLS

-it's *quicker*



MILLS SCAFFOLD CO. LTD.

(A subsidiary of Guest, Keen & Nettlefolds, Ltd.)

Head Office: TRUSSLEY WORKS, HAMMERSMITH GROVE, LONDON, W.6 • TELEPHONE: RIVERSIDE 3011

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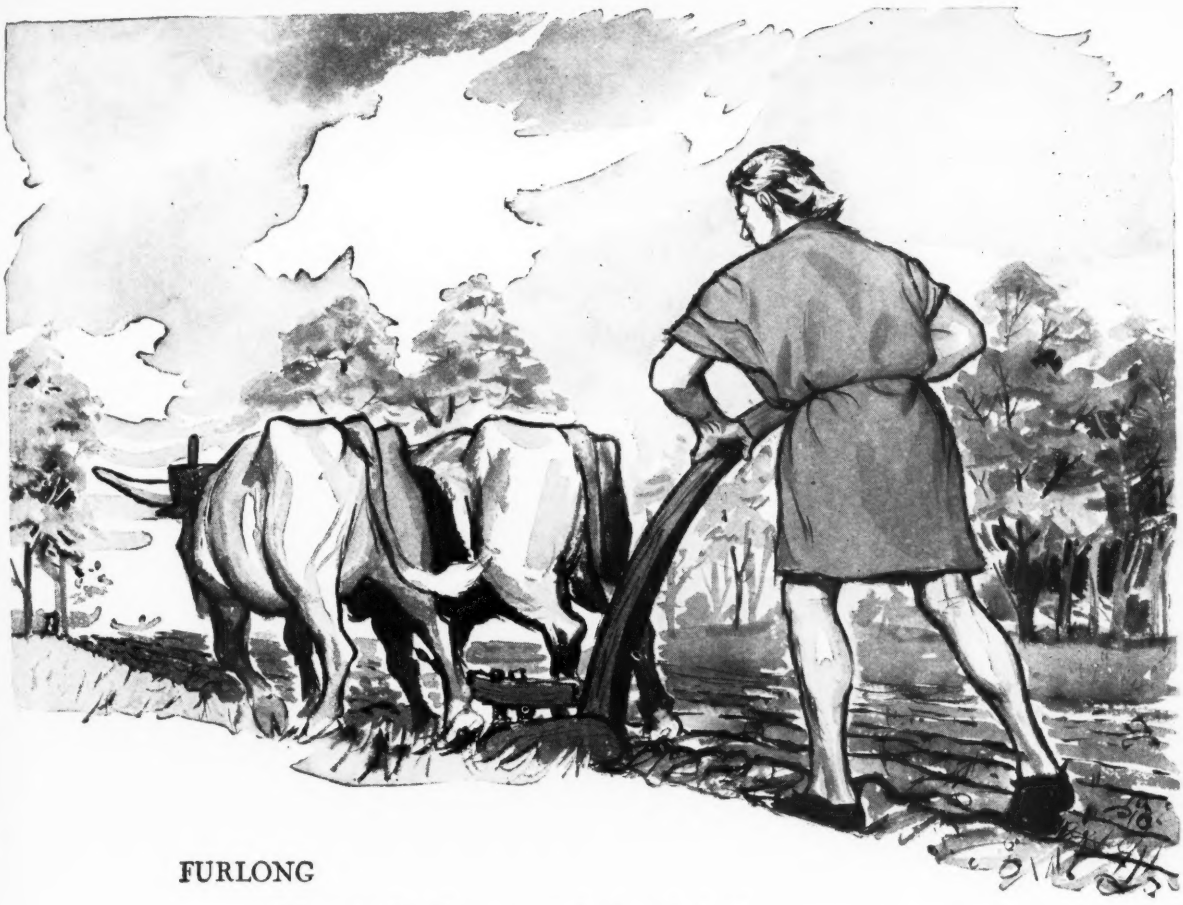


FURLONG

Was originally a Saxon measure based on the length of a furrow in a "common" field which roughly occupied a square of 10 acres. It was later standardised as 1/8th of a mile.

Over the years, standards have been evolved by man to meet his personal needs and to regulate his trade and general relationships with his fellows.

The main function of the British Standards Institution is to set up and maintain standards of quality, fitness for purpose and performance so that users may rest assured that they are obtaining value for money.

In some cases the existing procedure of a producer is accepted as the best practice of the art and is taken as a basis for the standard in question. Thus British Standard 1004 (Zinc Alloys for Die Casting) was based on the established practice of the Imperial Smelting Corporation in the production of MAZAK.

MAZAK

The Standard by which others are judged.

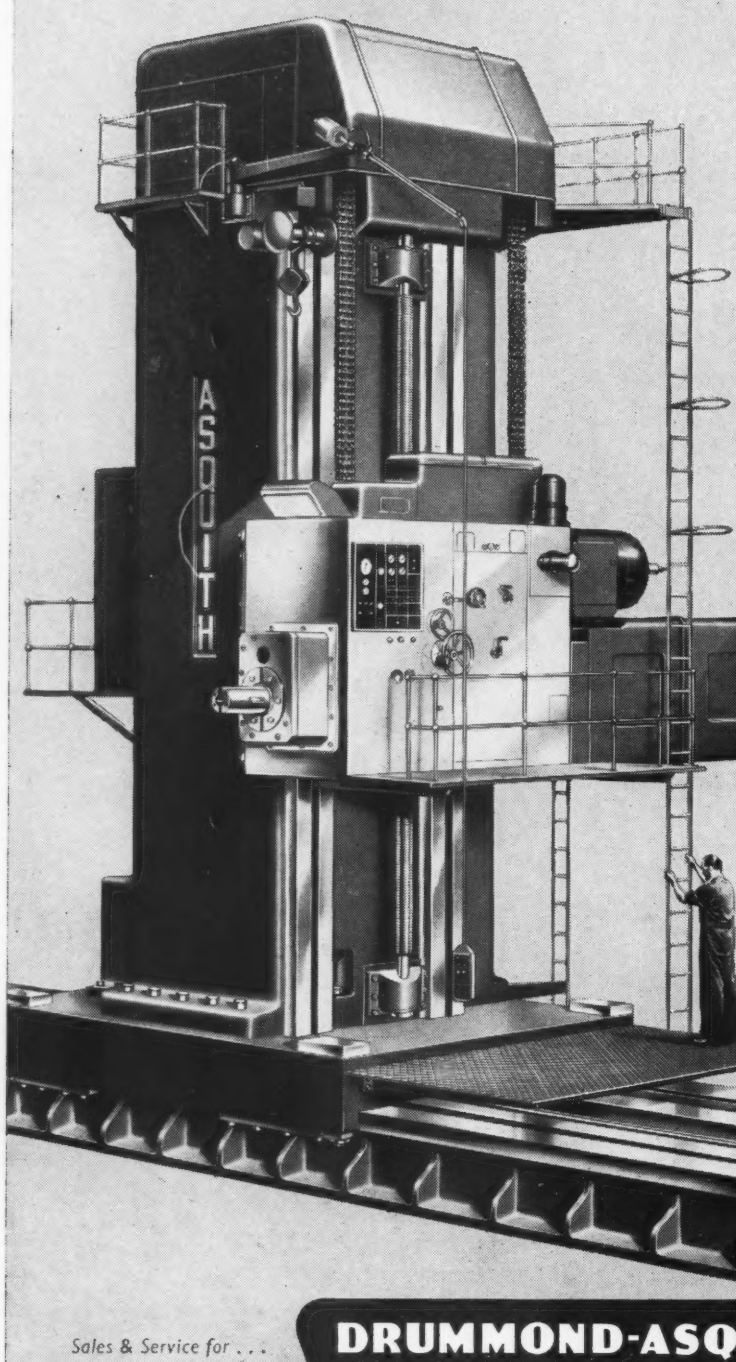
A PRODUCT OF IMPERIAL SMELTING

CONSOLIDATED ZINC CORPORATION (SALES) LIMITED, 37 DOVER STREET, LONDON, W.I.

ASQUITH

RAM TYPE

HORIZONTAL MILLING AND BORING MACHINE



This new Asquith machine has been designed to meet the need for dual purpose equipment in heavy machine shops, where great savings in time and cost are being effected by milling (instead of planing) and boring, drilling, tapping, etc., in many instances all at one setting of large components.

A ram and spindle are fitted and both heavy milling and boring can be carried out. The ram, of rectangular section, houses the milling sleeve and spindle; the front of the ram being provided with a facing to which can be bolted various types of milling attachments.

This type of Asquith machine is available in four sizes, with spindle diameter 6 in., 7 in., 8 in. or 10 in.

Write today for the Asquith Ram Type Borer Catalogue.

WILLIAM ASQUITH LTD.
HALIFAX·ENGLAND

Sales & Service for . . . **DRUMMOND-ASQUITH** *. . . the British Isles*

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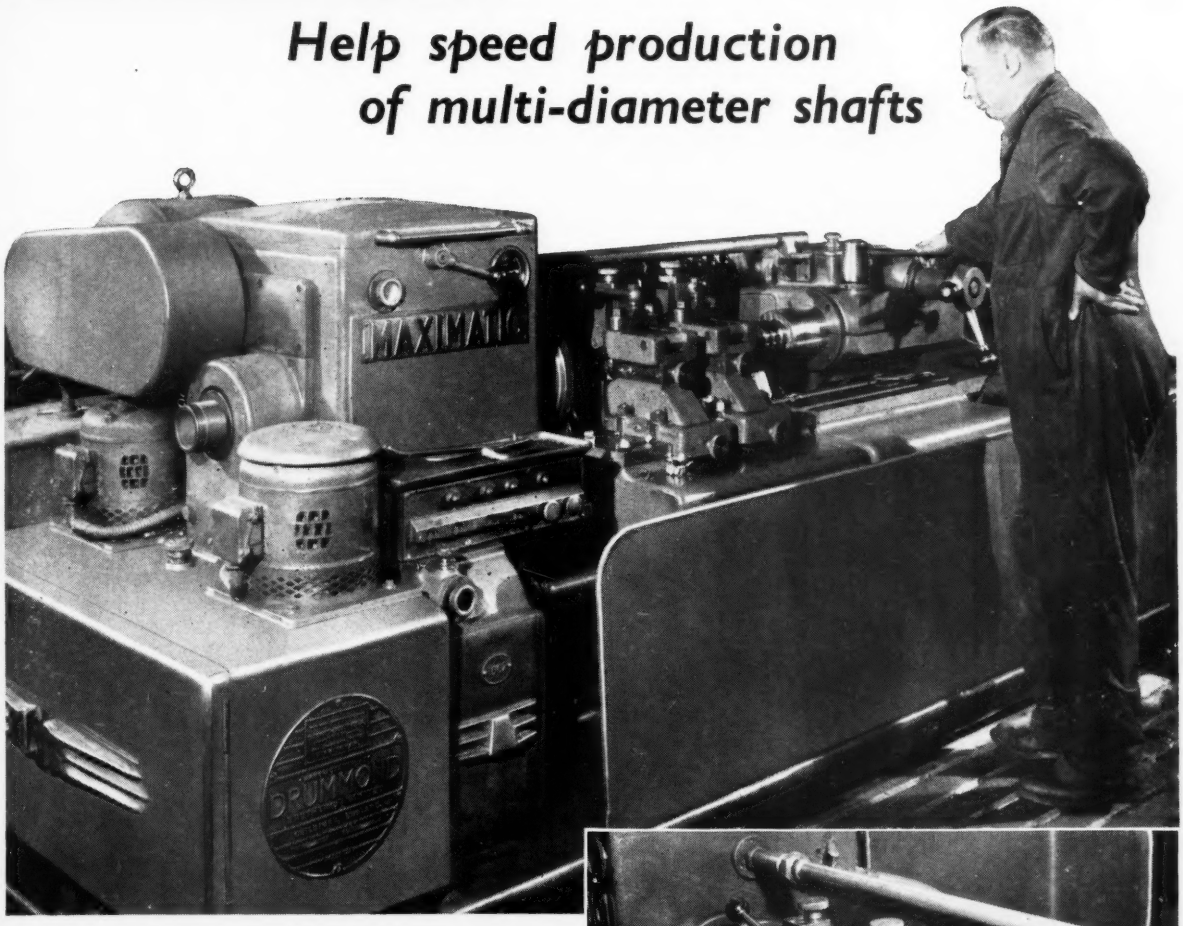
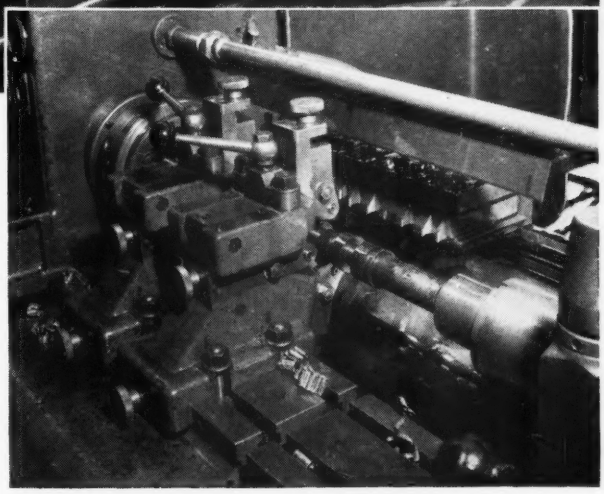
MAXIMATIC AUTOMATIC MULTI-TOOL LATHES

Help speed production of multi-diameter shafts





The "Maximatic" is shown tooled-up for turning steel camshafts. The operator's duties consist simply of unloading, loading and operating the main control lever. The tool slide carries out an automatic cycle of quick infeed, turn and quick return. All motors then stop ready for the component to be removed.

In the example shown, only the rear slide is employed for turning, but a combination of slides can be used for both turning and facing, each cross slide being independently operated by flat former plates, and adjustment can readily be made when a different component is required.

Drummond Automatic Multi-Tool Lathes are built in a range of sizes from 6 in. × 18 in. up to 15 in. × 102 in.

Write today for details of the size of machine which would interest you.

DRUMMOND BROS., LTD.
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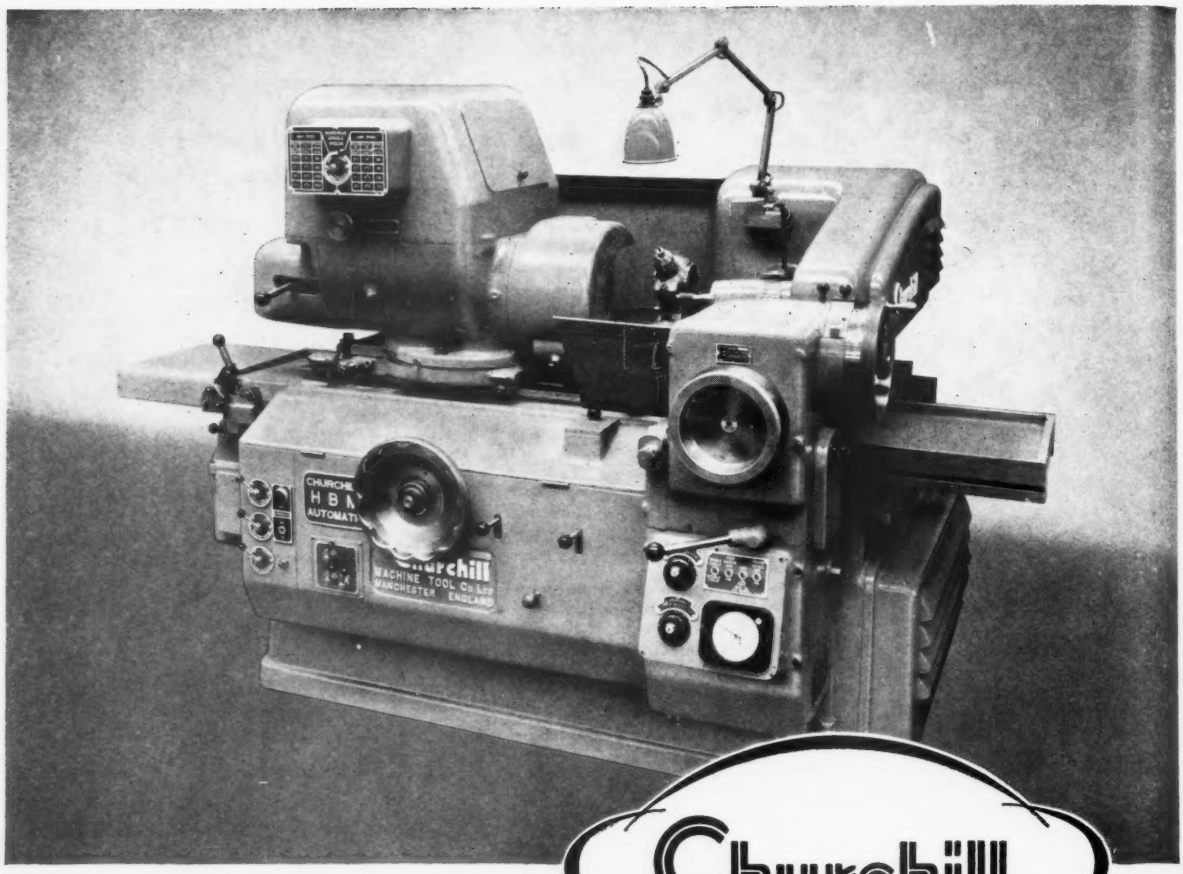

Churchill

HBM

AUTOMATIC SIZING INTERNAL GRINDING MACHINE

CHURCHILL Automatic Sizing Internal Grinding Machines are renowned for their accuracy and speed of production. The extensive experience gained from supplying very many machines has been fully utilised in the Model 'HBM' to ensure highly efficient operation over a wide range of work.

Single or double automatic cycle operation according to work.
Plunge cut and traverse grinding.
Feed accelerator reduces production time.
Exceptionally wide range of roughing and finishing feeds.
Diminishing rate of feed to zero with variable electric dwell at size position.
Adjustable oscillation for building-up finish on blind end and open short length bores.
Hand feed to dead stop for plain internal grinding.
Operational safety — provision for immediate interruption of automatic cycle for emergency run-out — enclosing of dogs and plungers eliminates "finger traps".
Can be equipped for combined hole and face grinding.

BRITISH MACHINE TOOL MAKERS ASSOCIATION LTD.

THE CHURCHILL MACHINE TOOL CO. LTD., BROADHEATH, nr. MANCHESTER.
Telephone: Altrincham 3262. Telegrams: Churchale, Manchester.
Export Sales Organisation: Associated British Machine Tool Makers Ltd., London, Branches and Agents.
Home Selling Agents: Charles Churchill & Co. Ltd., Birmingham and Branches.

PRECISION *plus* PRODUCTION

C661-ID

54·75" (52 min)
37·875" (32 min)
TYPICAL PROFILING FLOOR TO FLOOR TIMES
model J 6
Unitrace Profiling
Lathe
16·06" (9 min)
2·5
(13 min)
24·625" (19 min)
LANG
PROFILING
TURNING
BORING
SURFACING
+
STANDARD SLIDING
SURFACING & SCREWCUTTING
LATHE ALL IN ONE MACHINE
43·25" (73 min)
LONDON OFFICE
ASSOCIATED BRITISH MACHINE
TOOL MAKERS LIMITED
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ASSOC. BRITISH MACHINE TOOL MAKERS LTD
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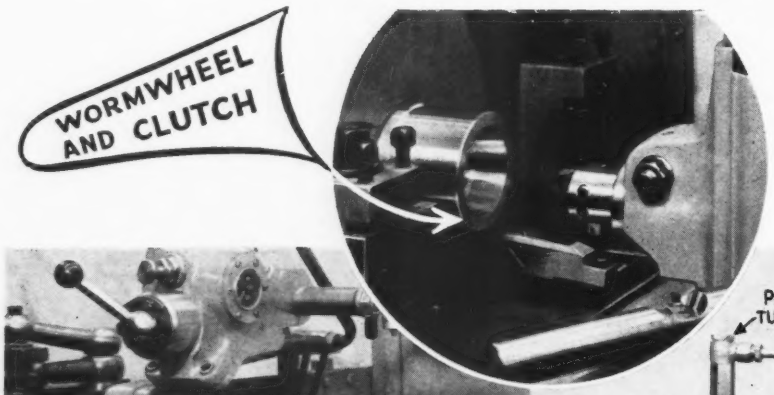
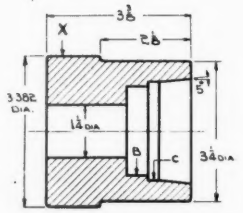
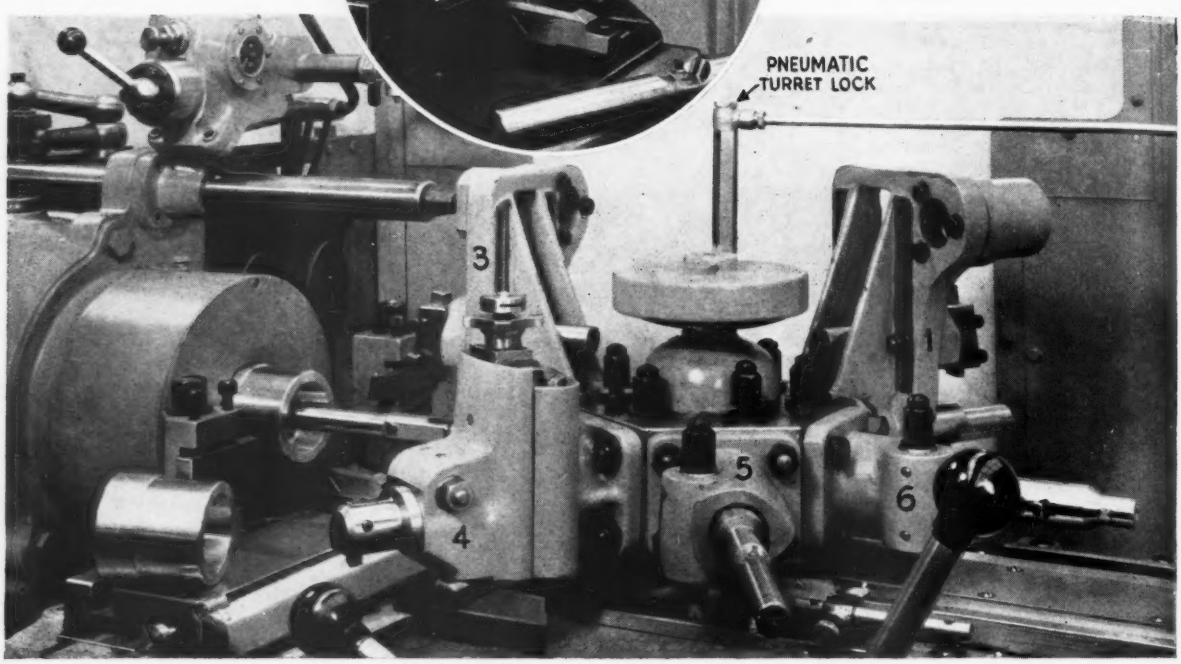
L218-1

Maximum Production Special Tool Layouts







Ward

No. 3A CAPSTAN LATHE

FITTED WITH 7½in 3-JAW AIR CHUCK

Tungsten Carbide Cutting Tools

PHOSPHOR BRONZE CASTING

Floor-to-Floor Time: 3 mins. 10 secs. each.

DESCRIPTION OF OPERATION	Tool Position		Spindle Speed R.P.M.	Surface Speed Ft. per Min.	Feed Cuts per inch
	Hex. Turret	Cross-slide			
1. Chuck on X	—	—	—	—	—
2. Rough Face End	—	Rear	540	480	Hand
3. Rough Bore 1¼" and Knee Turn 3¼"	1	—	540	480	125
4. Finish Bore B and C	2	—	955	624	125
5. 2nd Bore 1¼" dia. Finish Knee Turn 3¼"	3	—	955	812	125
6. Face End and Radius	—	Front	1650	1404	Hand
7. Taper Bore (2 Cuts)	4	—	1650	1080	234
8. Microbore 1¼" dia.	5	—	1650	540	234
9. Chamfer Corners	6	—	1650	1080	Hand
10. Remove	—	—			

H·W·WARD & CO LTD

SELLY OAK
BIRMINGHAM 29

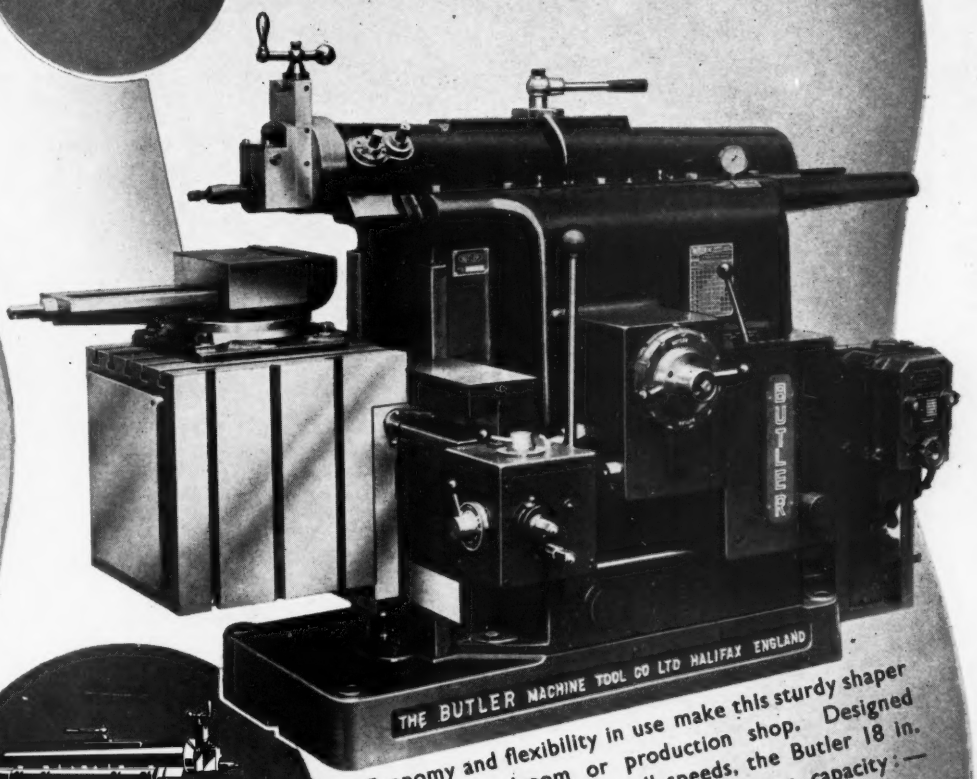
TELEPHONE SELLY OAK 1131

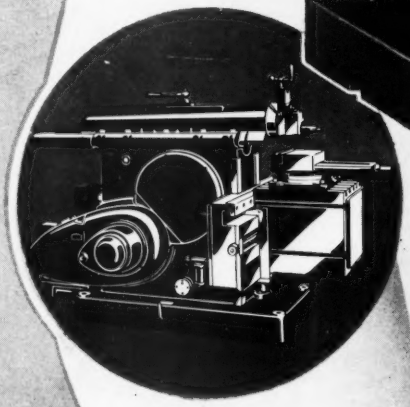
BRITISH MACHINE TOOL MAKERS' ASSOC. LTD

W652

Butler

18" SUPER SHAPER





Economy and flexibility in use make this sturdy shaper ideal for toolroom or production shop. Designed for smooth operation at all speeds, the Butler 18 in. stroke Super Shaper has the following capacity:—

Table top 18 in. long x 17½ in. wide
Table side 18 in. long x 17 in. wide
Table travel 20 in. horizontal
Table admits 12 in. under toolbox
Range of speeds 15-150 cycles per minute.

The BUTLER MACHINE TOOL Co. LTD
HALIFAX ENGLAND

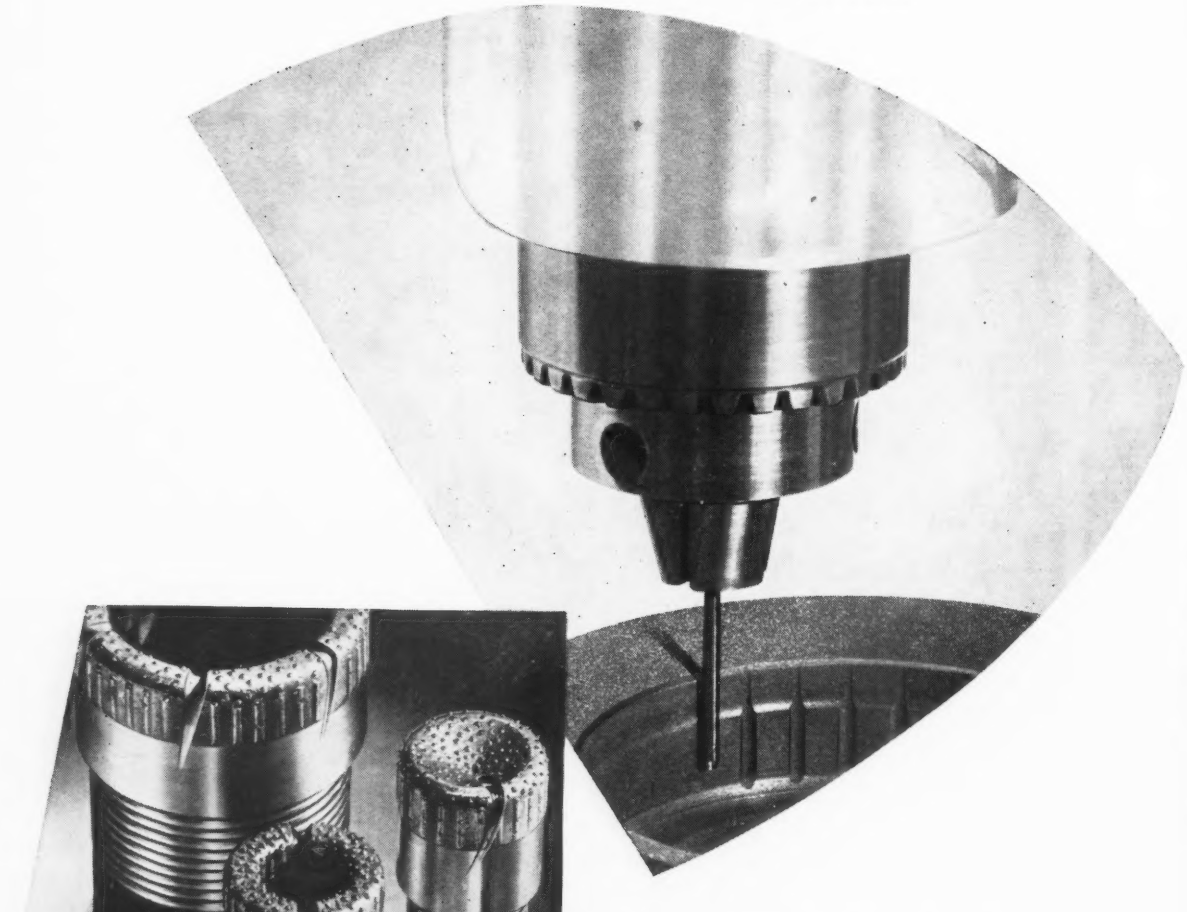
FOR PRECISION PLANERS SHAPERS SLOTTERS

BRITISH MACHINE TOOL MAKERS ASSOCIATION LTD

B2JJA

DIAMOND *cut* DIAMOND

We use our own products



Carbon moulds are used in the production of Diadril mining equipment. To ensure consistent accuracy in the finished product we machine the mould cavities with specially designed Diatipt cutters

LM

VAN MOPPES & SONS (DIAMOND TOOLS) LTD
BASINGSTOKE · HAMPSHIRE · ENGLAND

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OUR ILLUSTRATED DATA SHEETS AND OUR TECHNICAL REPRESENTATIVES ARE AVAILABLE ON REQUEST

JW.5

Cut your costs with

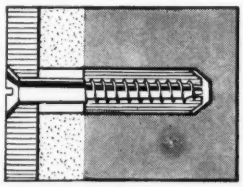
21 RAWLPLUG FIXING DEVICES

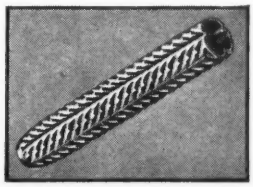
FOR SPEEDY FIXING IN ANY MATERIAL

No more trouble or costly delay because the material was 'difficult'! Whether it's concrete or plastic, breeze or sheet metal, cavity brick or lath and plaster, there's a Rawlplug Fixing Device that makes firm screw or bolt fixings quickly, easily and economically. The speedy answer to every fixing problem is one or other of the 21 different types of Rawlplug Fixing Devices. Write for illustrated brochure.

Screw Fixings

Use the famous RAWLPLUG for neat, firm fixings in brick, stone, etc. All sizes up to ¾" diameter Coach Screws. Rawlplugs are waterproof and unaffected by climatic conditions.

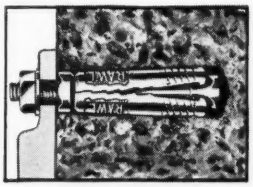


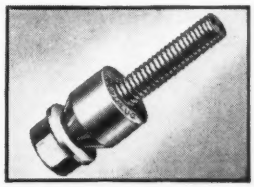


Rawlplug WHITE BRONZE PLUGS are specially suitable when the fixing is subject to very high temperatures, such as the outer brick coverings of furnaces. Use also for under-water fixtures.

Bolt Fixings

For bolting down machines, use RAWLBOLTS, a dry fixing that grips by expansion. No cold chiselling, no waiting for cement to harden. Sizes up to 1" bolt diameter.

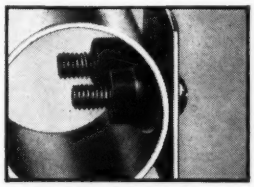


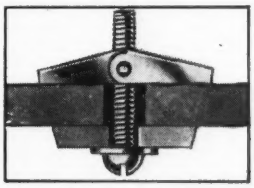


Use Rawlplug BOLT ANCHORS for bolting down in extremely wet or corrosive situations. Caulking completely seals the anchorage. Use also for anchoring Diesel Generators, Power Hammers, etc.

Cavity Fixings

Screwed up from the front the amazing RAWLNUT forms its own rivet head behind the material—airtight, watertight, vibration-proof, squeak-proof! For all thin or hollow materials.





For ceilings of lath and plaster, plasterboard, etc., use Rawlplug SPRING TOGGLES. The inserted Toggle springs open behind the material, spreading the load over a wide area.

USED BY THE MILLION THROUGHOUT INDUSTRY

RAWLPLUG WALL PLUGS

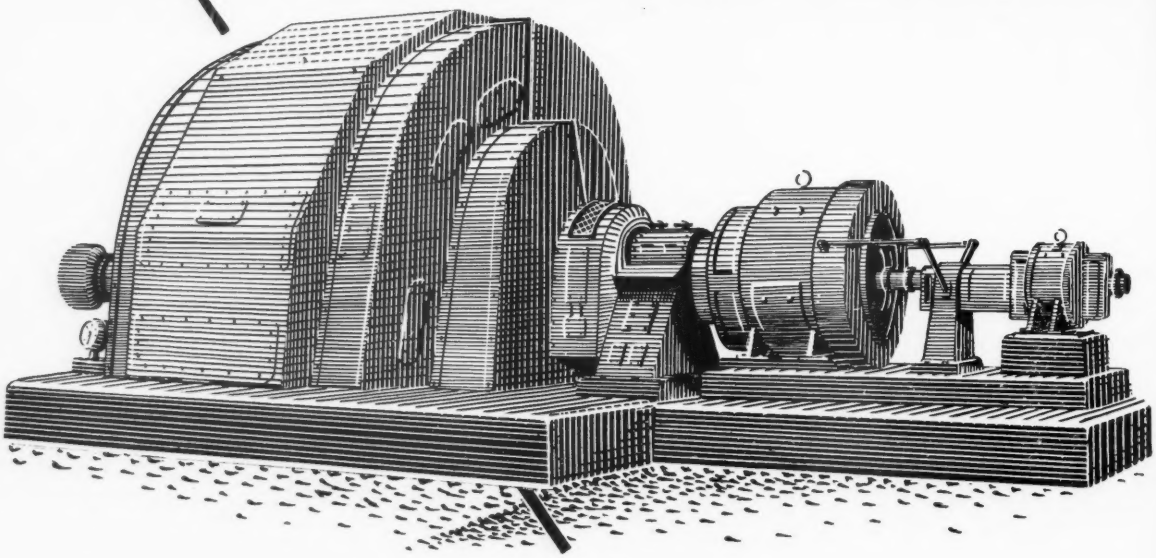
FIXING DEVICES

21 *different types of fixing devices for Speed and Strength*

B559

Made by THE RAWLPLUG CO. LTD., CROMWELL ROAD, LONDON, S.W.7
The World's largest Manufacturers of Fixing Devices.

We at Kirkstall have been working iron or steel for over seven hundred years.



Industrial Revolutions . . .

Mighty modern machines upon which the wheels of a whole industry may depend must be perfect and completely reliable. Knowing this, designers are wise indeed to specify their Bright Steel Bar requirements from Kirkstall.

Kirkstall Forge

Leeds 5 · Yorkshire

TELEPHONE: HORSFORTH 2821

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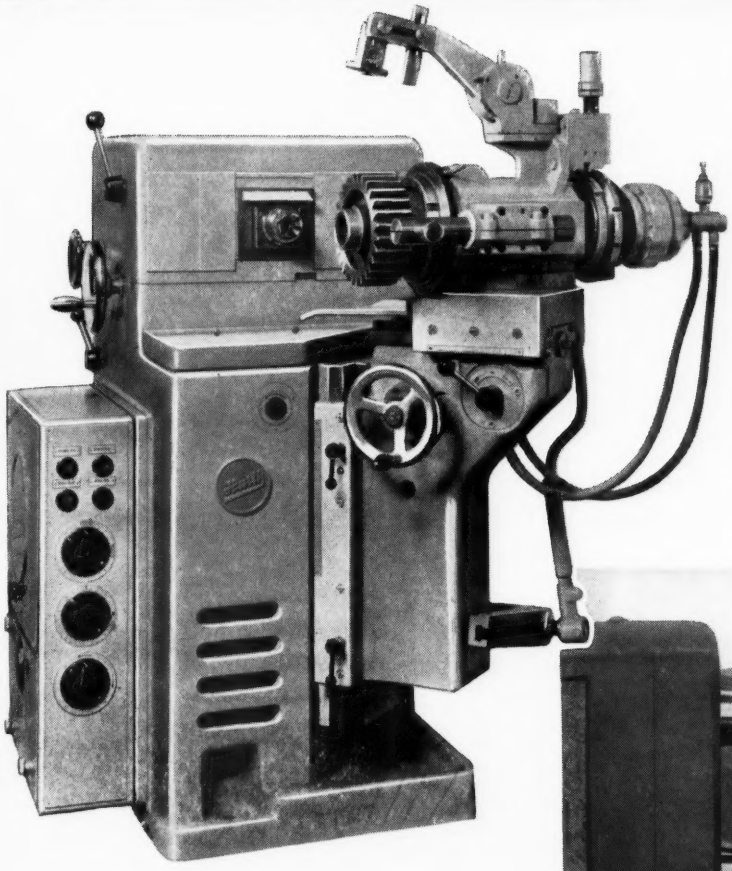
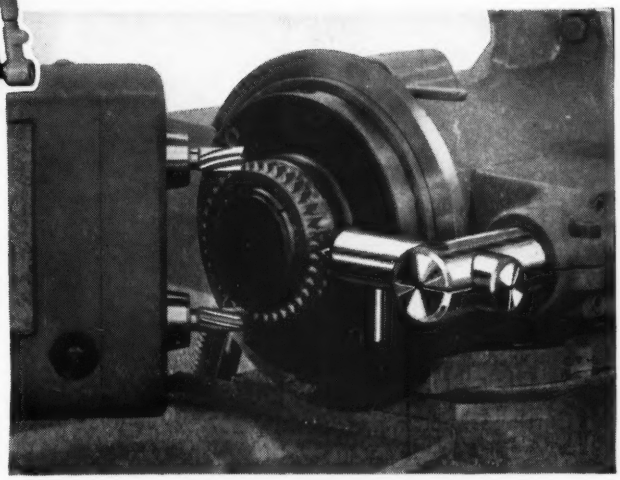
HURTH AUTOMATIC



GEAR TOOTH ROUNDING & DE-BURRING MACHINES

TWO SPINDLE HEAD AVAILABLE FOR VOLUME PRODUCTION



Fast approach of bell-type cutter, self indexing after reaching pre-set depth and automatic stopping on completion of cycle, make the HURTH Model ZK4 an ideal machine for batch work on spur and helical gears, starter rings, clutches, etc. Maximum work-piece dia: 12". Range of teeth rounded: chamfered or de-burred 25-6 D.P., 7-110 teeth per gear. Speeds up to 120 teeth per minute.

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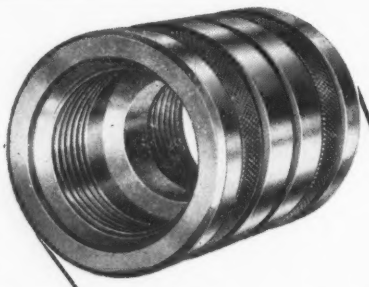


128

PIECES PER HOUR

FINISHED COMPLETE *"BOTH ENDS"*

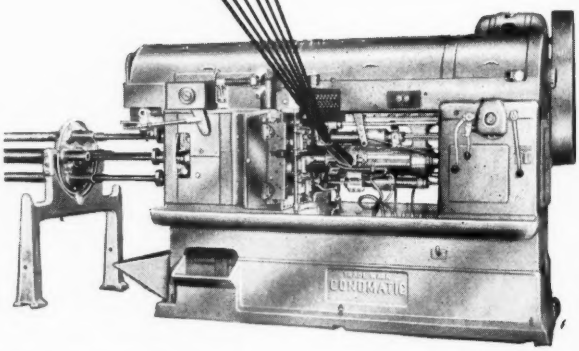
ON THESE BRITISH BUILT
1 5/8" DIA. 6 SPINDLE

CONOMATICS

JOB SET UP

Component	$\frac{3}{4}$" union
Material	F.C.M.S.
Stock dia.	$1\frac{7}{16}$"
Spindle r.p.m.	764
Cutting ft. per min.	287
Time per part	28 secs.
Hour prod. gross	128

PROMPT DELIVERY



CHARLES **CHURCHILL** & CO LIMITED

COVENTRY ROAD SOUTH YARDLEY BIRMINGHAM 25

BRANCHES LONDON GLASGOW NEWCASTLE MANCHESTER

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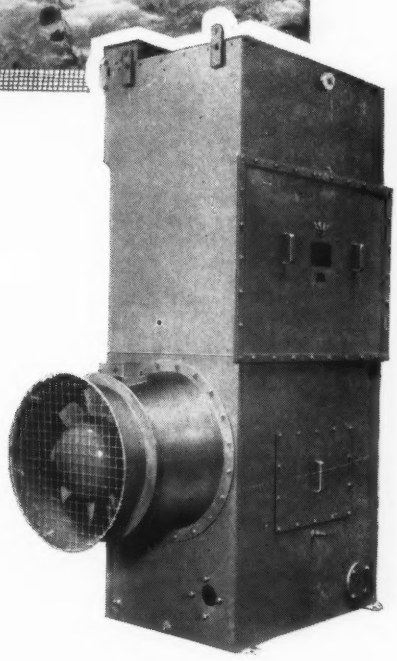
Save Water

Utmost Saving with

HEENAN
WATER COOLERS



In any process in which heat must be removed by water, very attractive financial savings can be secured by continuously re-cooling and re-circulating the water.

Consult us on your needs.

H&F

HEENAN & FROUDE LTD :: WORCESTER :: ENGLAND

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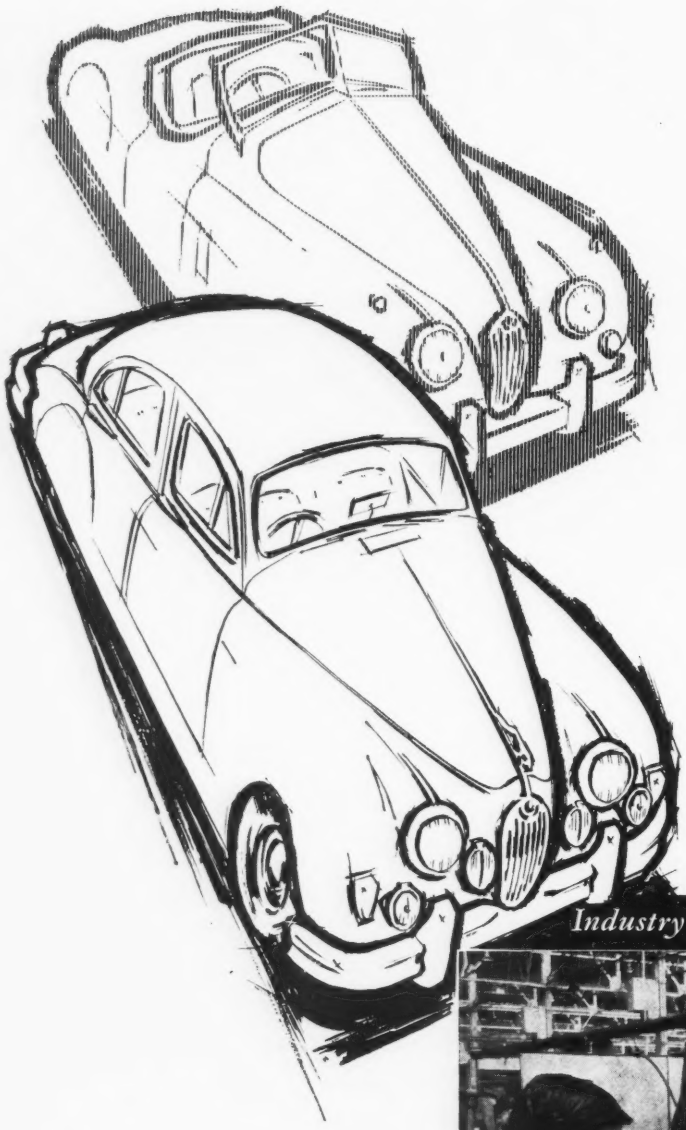

JAGUAR

accelerates production with

SNOW

DUPLEX DISC GRINDER

SURFACE SNOW GRINDERS

Industry's biggest names use **SNOW!**

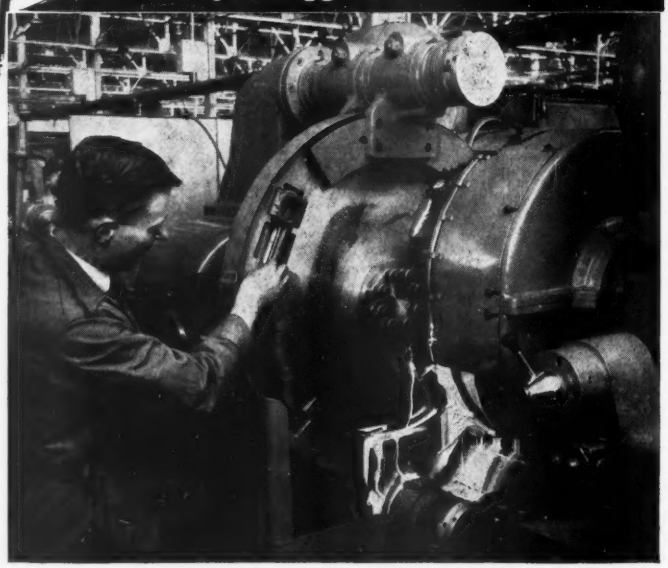

Photo by courtesy of Metalworking Production

By installing a Snow duplex disc grinder, Jaguar Cars Limited boost output of connecting rods to four per minute (a 900% increase).

SNOW & CO. LTD. *Machine Tool Makers* **STANLEY ST. SHEFFIELD 3**

LONDON *58 Victoria Street, S.W.1.* **BIRMINGHAM** *Daimler House, Paradise Street*

No bottlenecks here !...

Verticalautos at work

Smoothly, swiftly, economically, production flows along without hindrances where Verticalautos are at work! The work is loaded, a control is pressed; the six spindles index automatically through five working stations where auto-fed tools perform a succession of drilling, forming, tapping, milling operations and the job returns for unloading —finished or in a steady stream to the next machine. Minimum handling, minimum labour, minimum time . . . .

This is modern high-speed production at its smoothest. There's a place for it in your *plant too.*

THOMAS RYDER & SON LTD
TURNER BRIDGE WORKS
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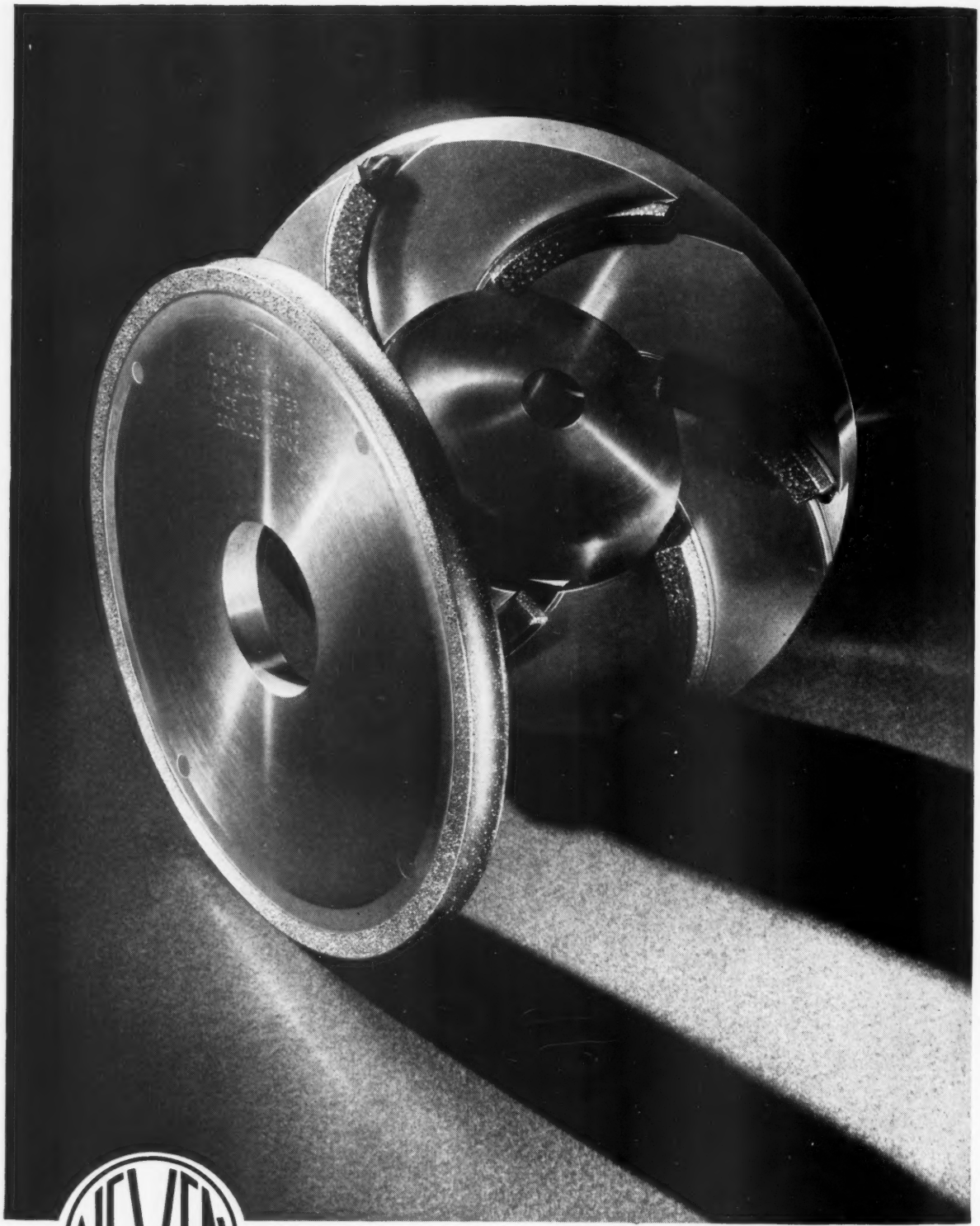

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2

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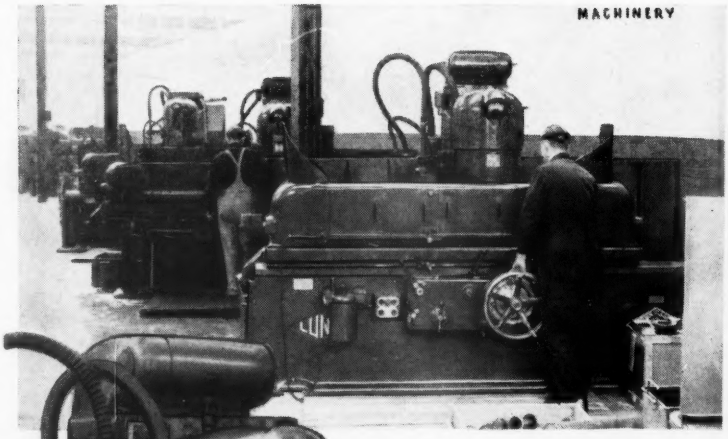

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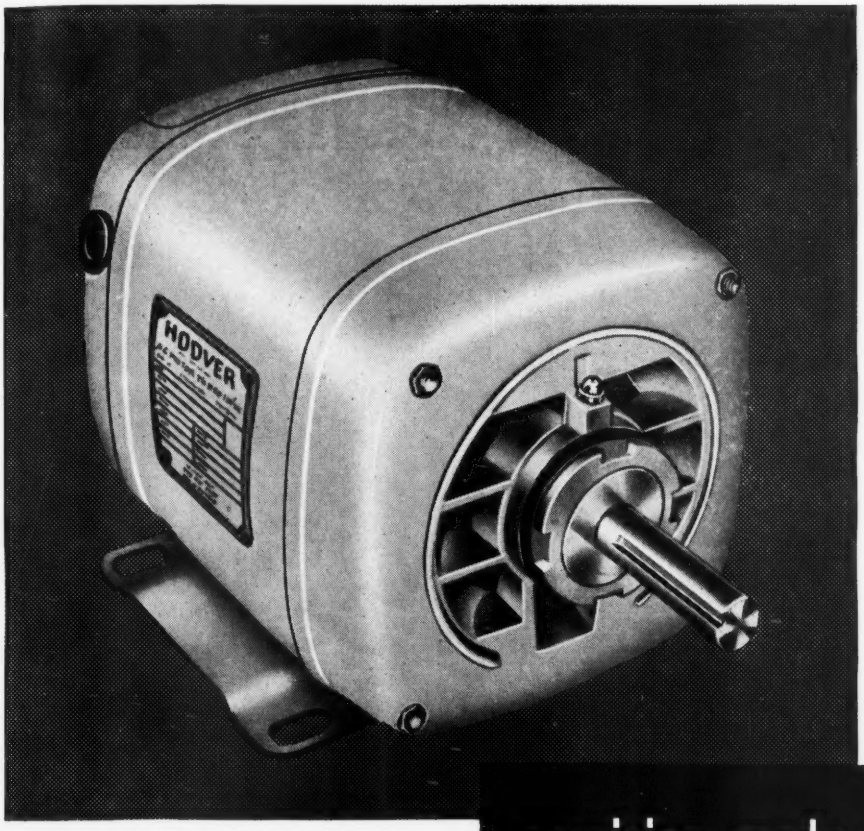

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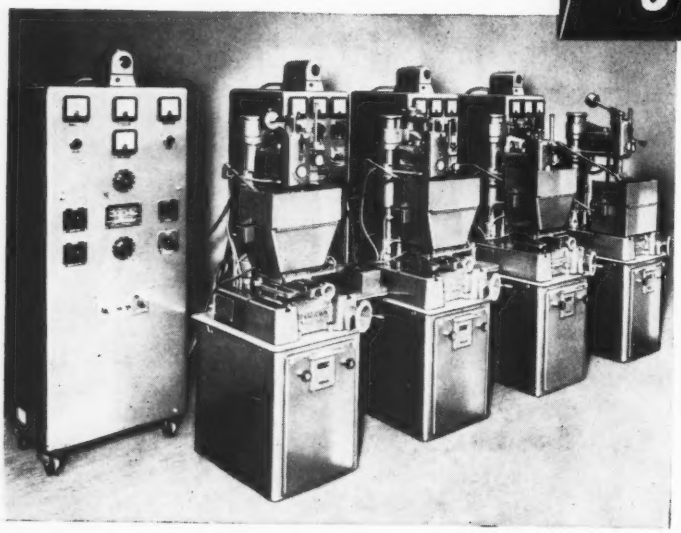

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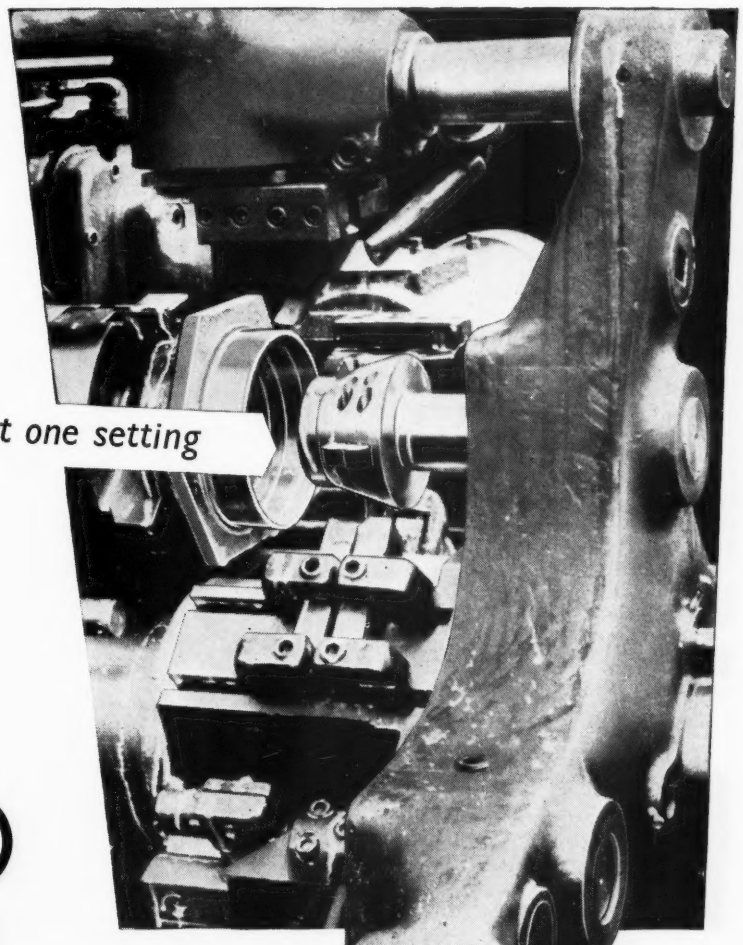

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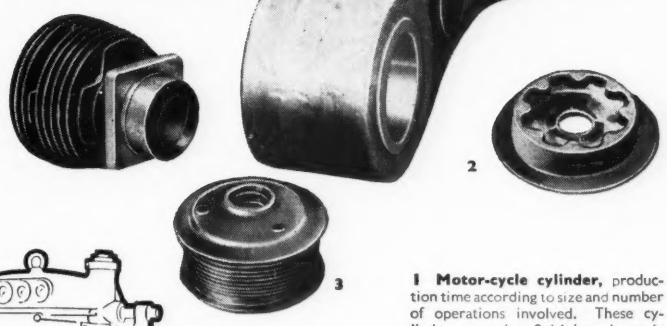

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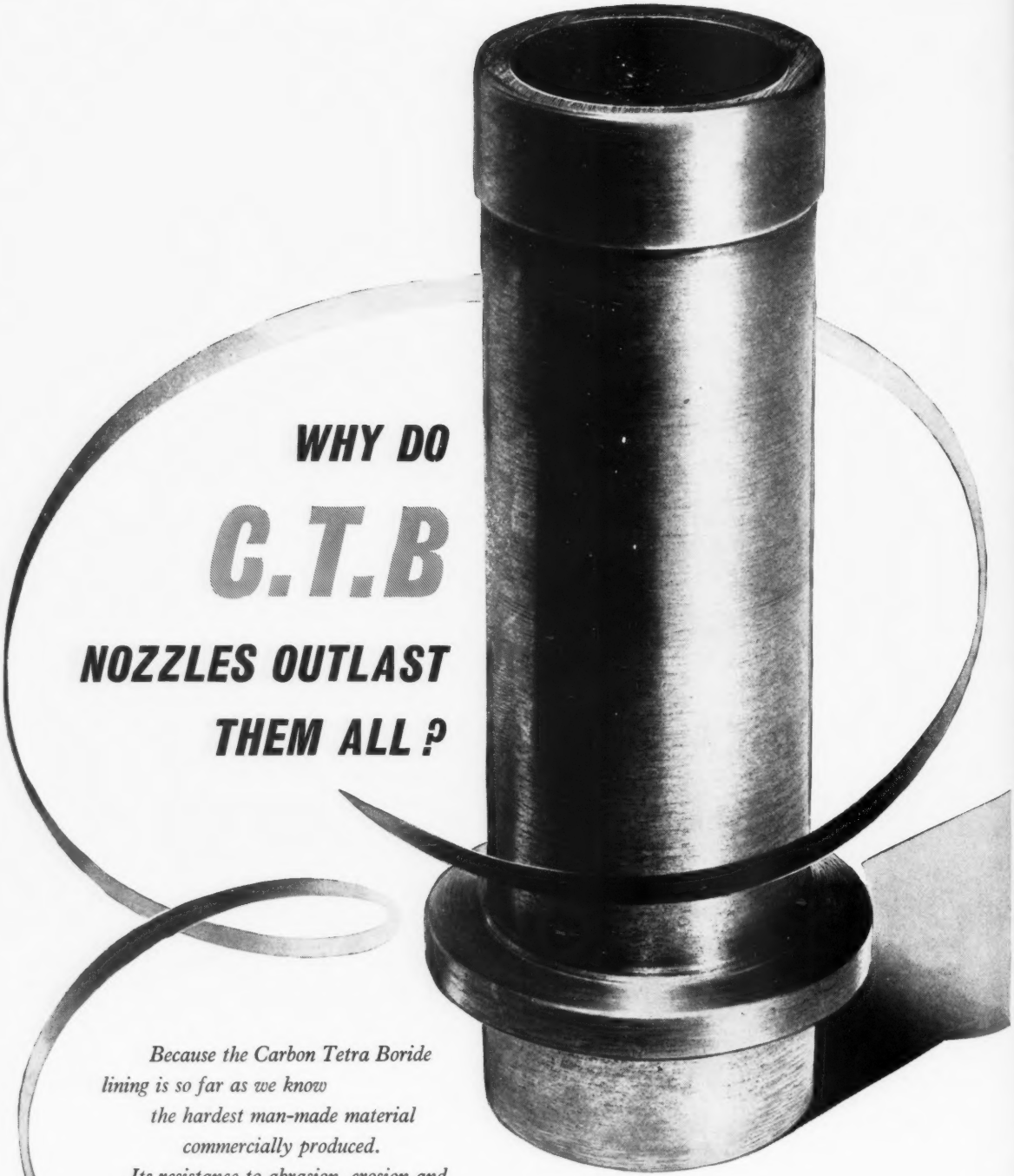

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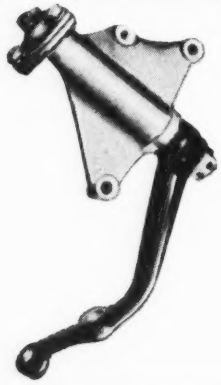

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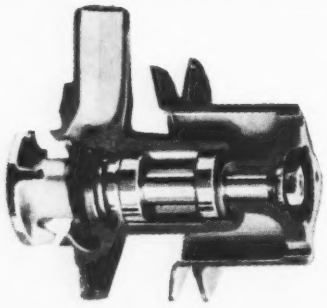

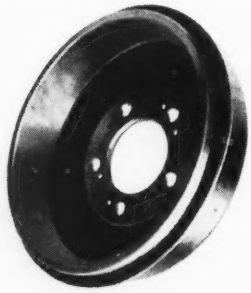

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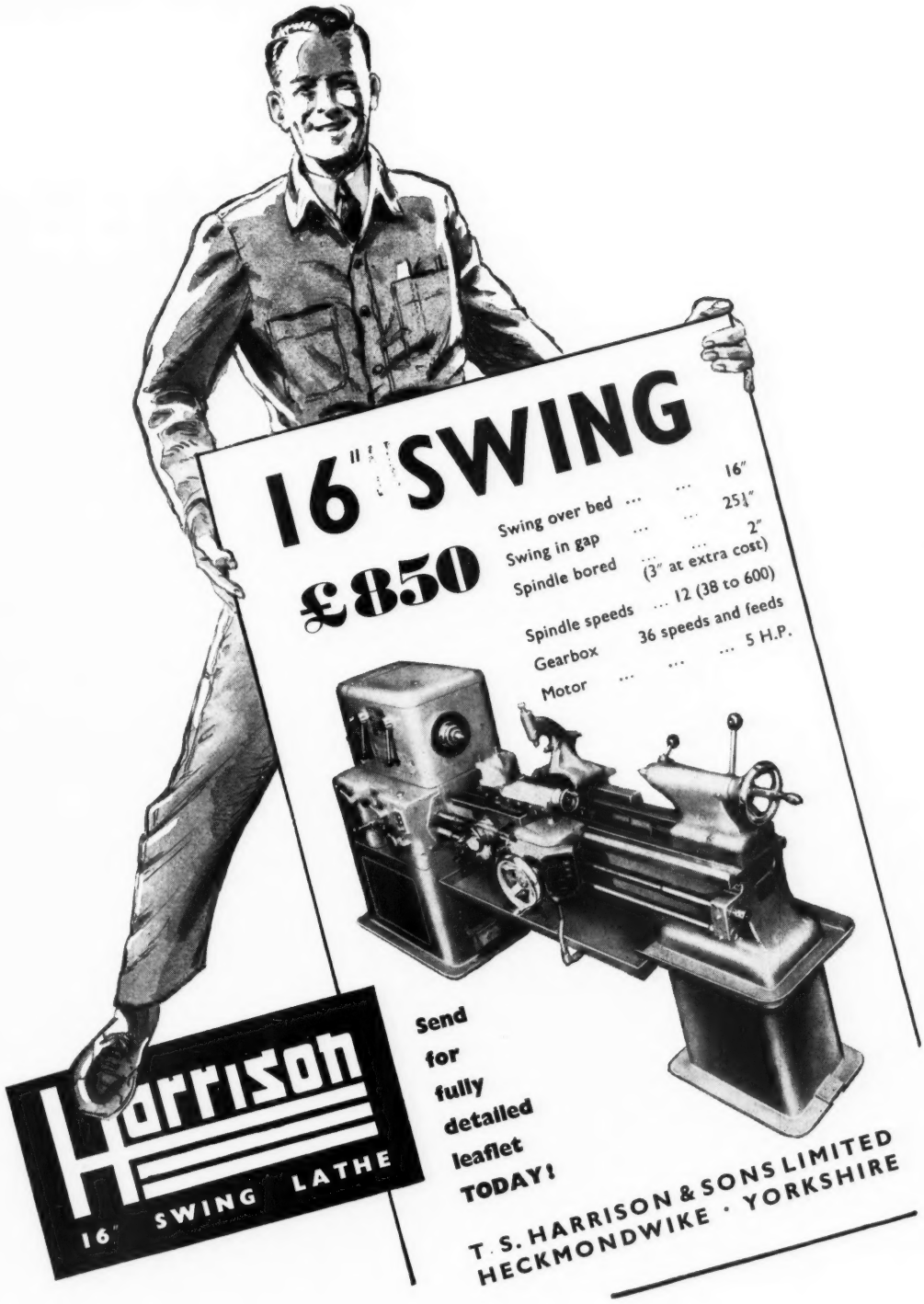
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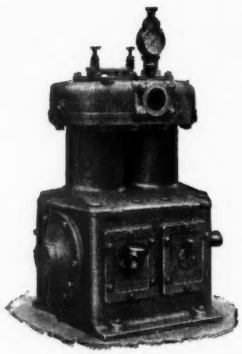

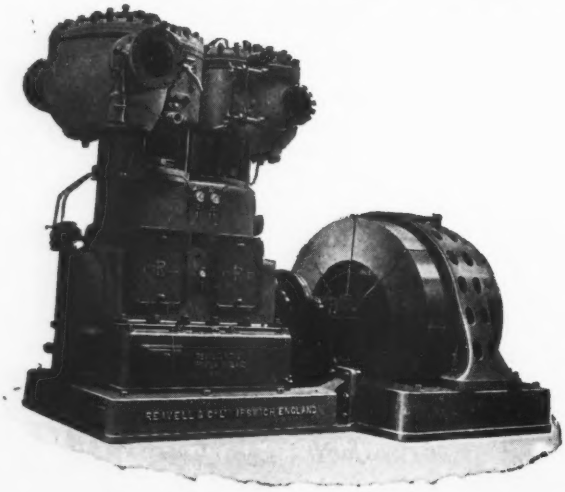

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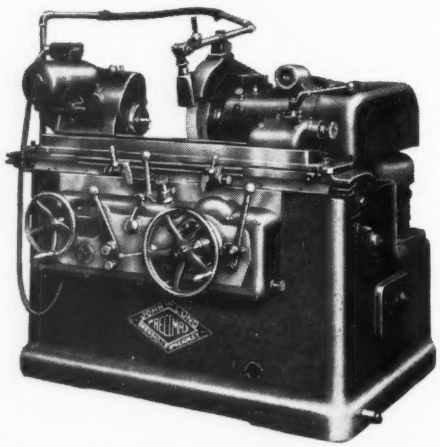

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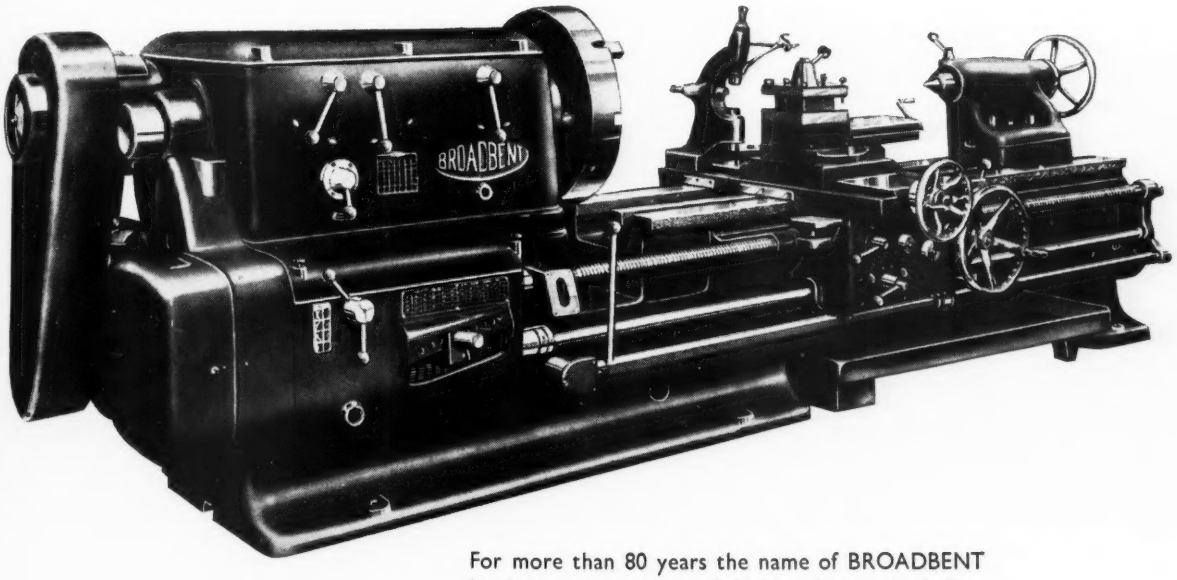

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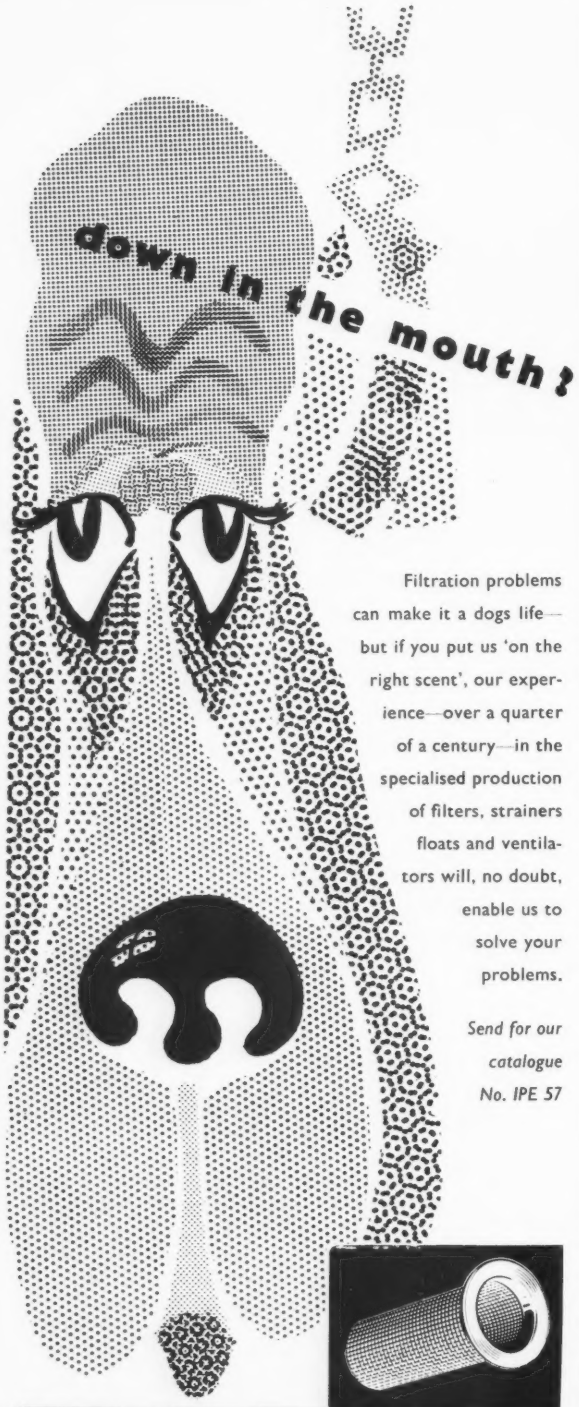

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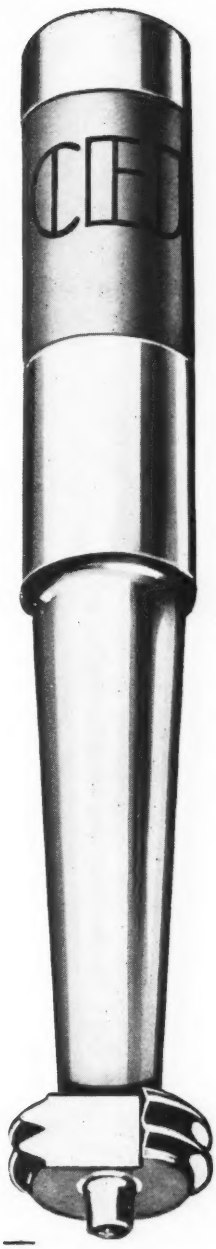

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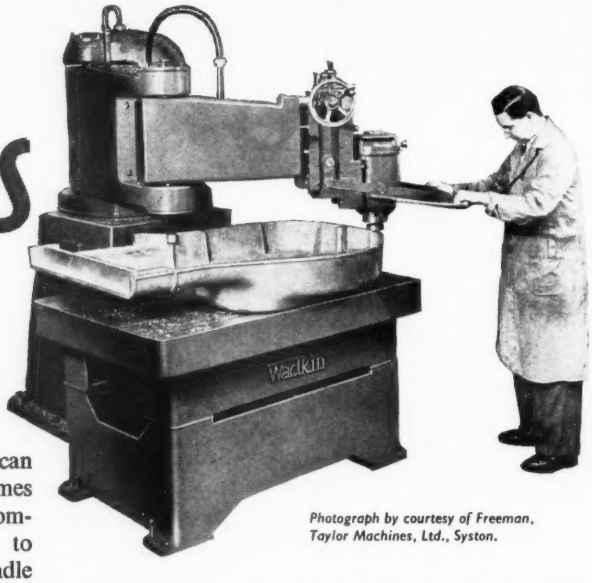
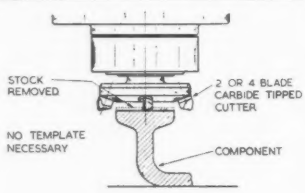


Photograph by courtesy of Freeman, Taylor Machines, Ltd., Syston.



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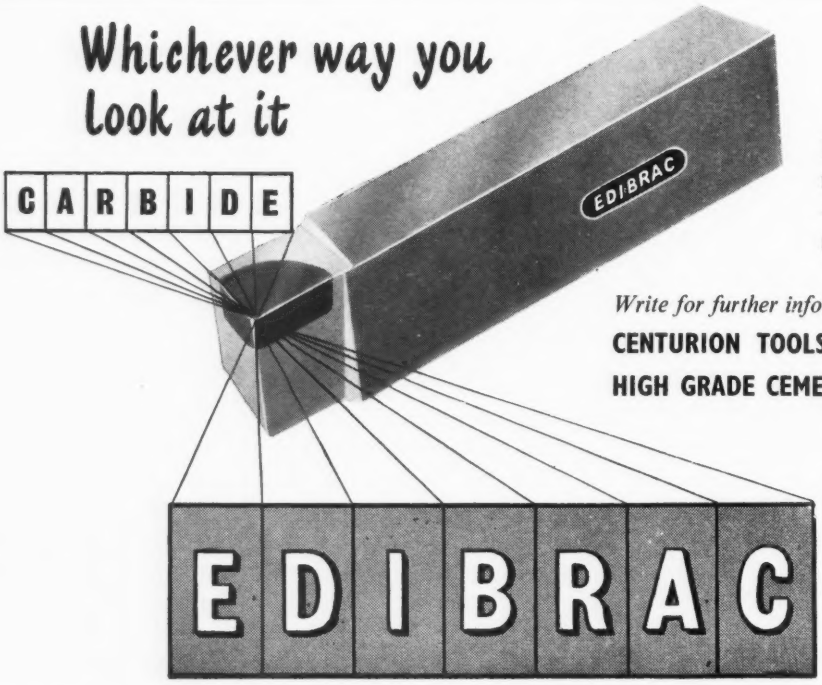

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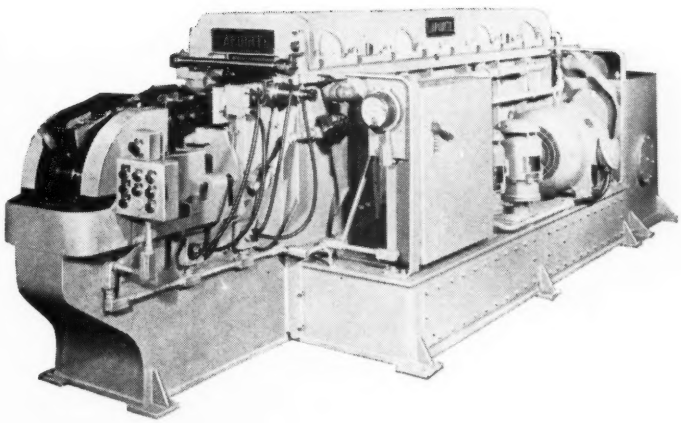

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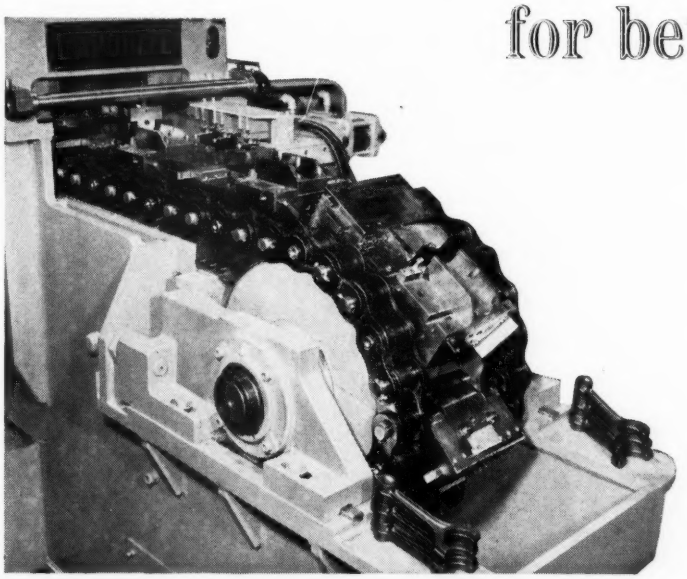

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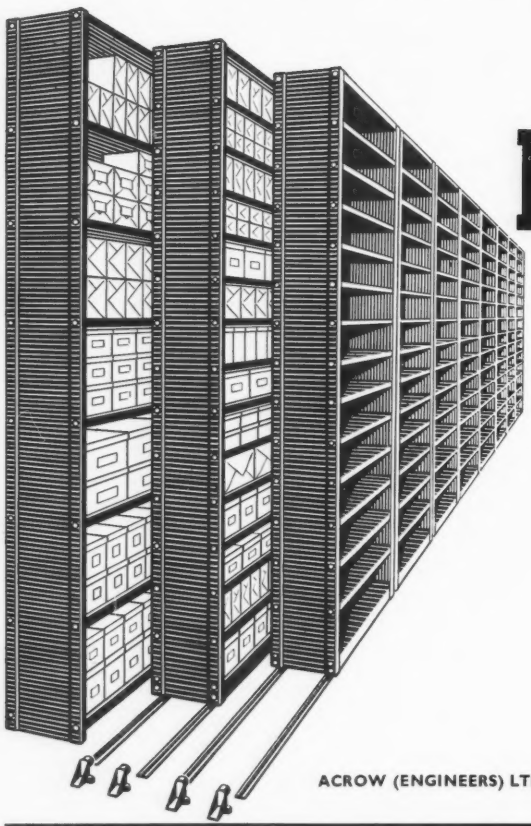

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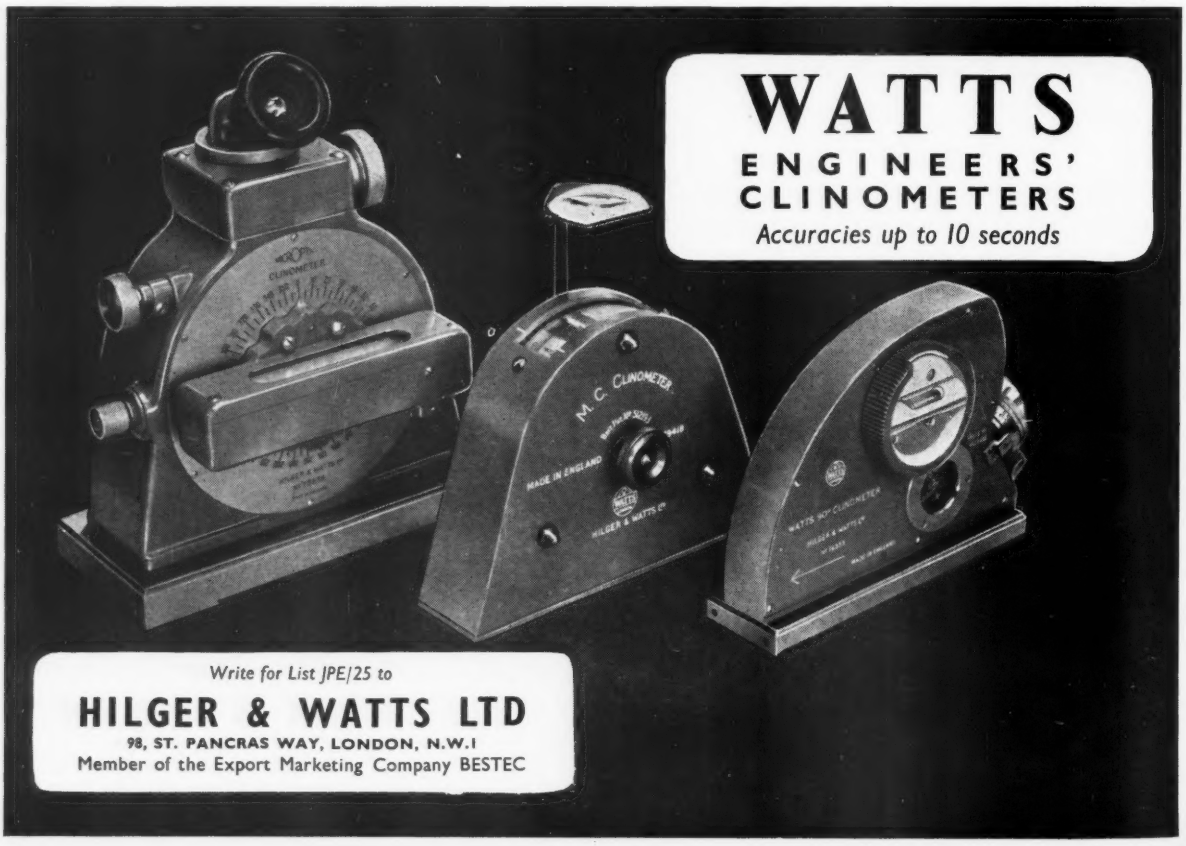

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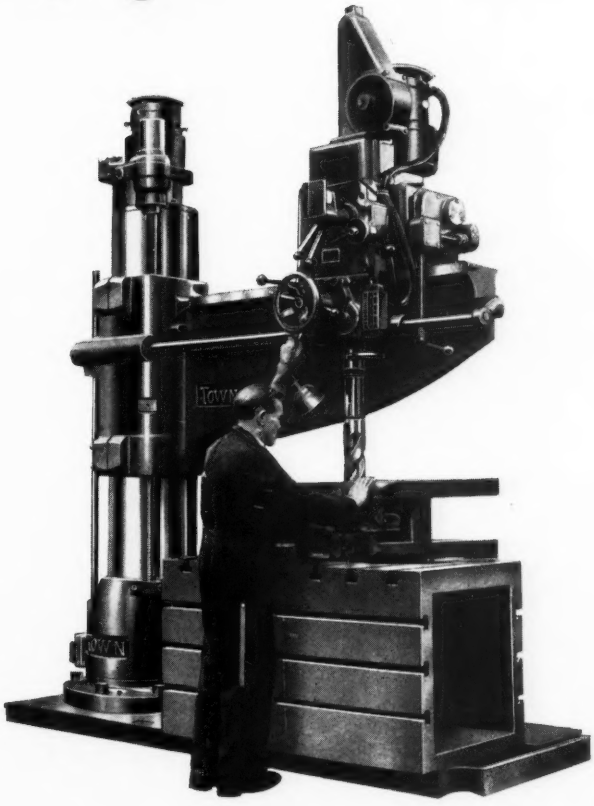

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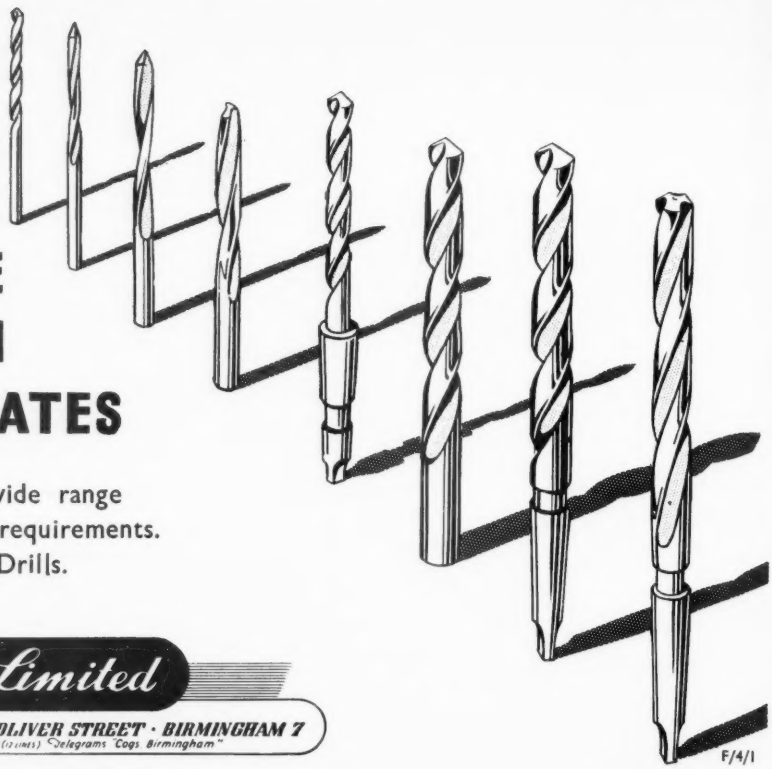

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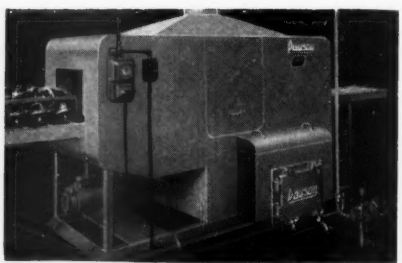

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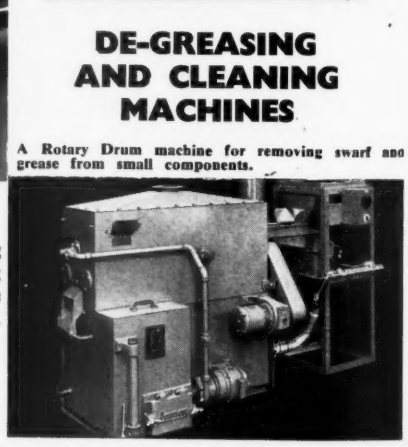

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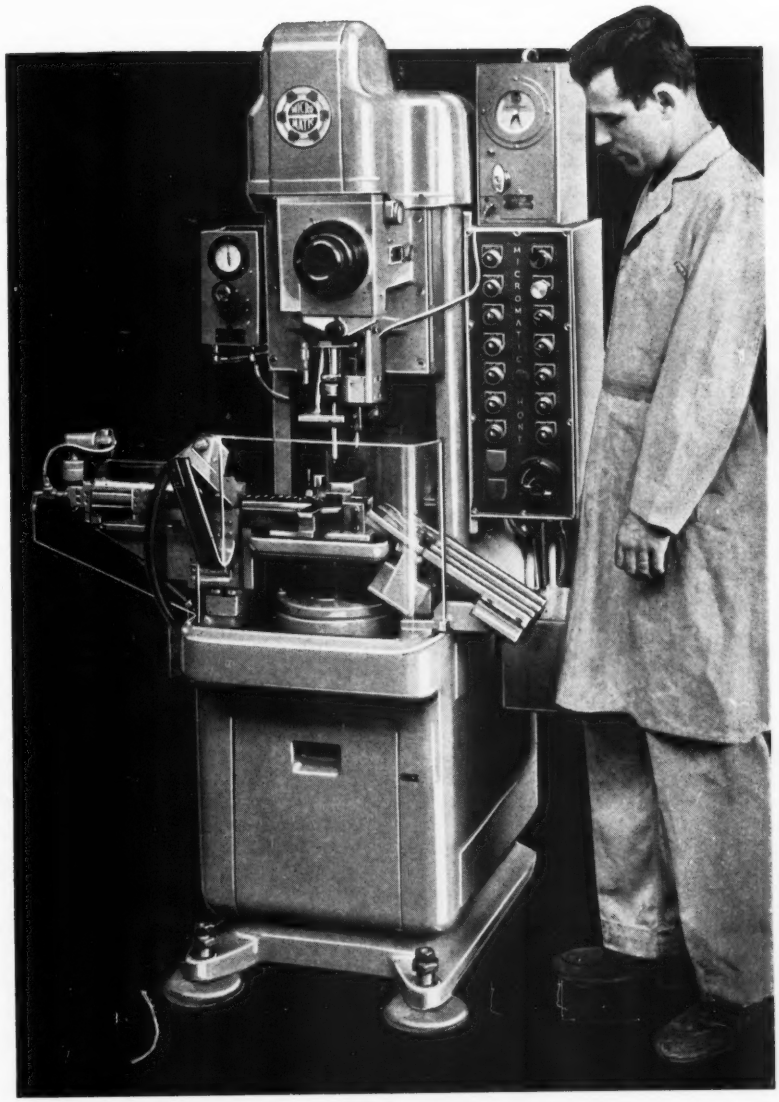
MODEL 738
MICROHONER

This model has recently been introduced to meet the demand for a honing machine to accommodate small diameter components for honing bores from $\frac{1}{4}$″ to 1″ diameter.



The Model 738 can be offered in two types, as a **simple hand feed machine,** or **fully automatic,** for sizing the bores, gauging and segregating according to tolerances required.

Micromatic Products are made and sold by us under U.S. Licence.

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NARBOROUGH ROAD SOUTH, LEICESTER
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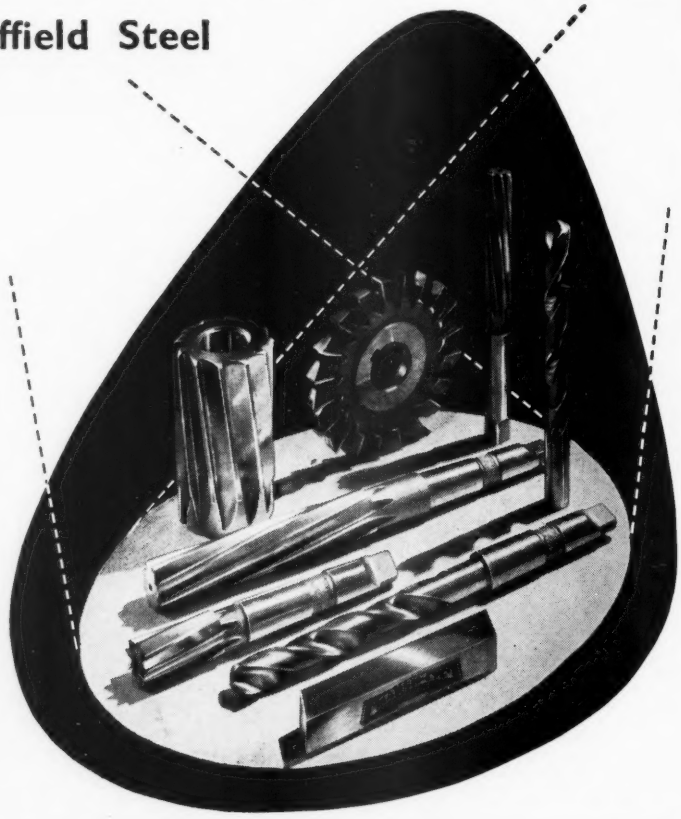

MARSH BROTHERS

of Sheffield England

PATENT CALIPER GAUGE MODEL 52

Each month one of the seven main advantages of this fine precision instrument will be described.

★● Many different gauging positions can be obtained.

● The anvils are set so that they do not roll.

● All shearing action is eliminated.

● Particularly suitable for gauging shouldered work.

● Can be used for either left or right hand threads.

● Particularly suitable for the gauging of acme forms of thread.

● Can be supplied for "GO" only, or "NOT GO" only, or both "GO" & "NOT GO" combined.

NOTE THIS MONTH'S IMPORTANT FEATURE

★ **MANY DIFFERENT GAUGING POSITIONS CAN BE OBTAINED**

Both GO and NOT GO Jaws are adjustable and, as the gauging surfaces are radial and are eccentrically mounted, numerous gauging positions can be obtained and the necessity for re-grinding eliminated. The length of life is, therefore, greatly prolonged.

Write today for a descriptive leaflet to:-

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THE HORSTMANN GEAR CO. LTD., NEWBRIDGE WORKS. BATH. ENGLAND.

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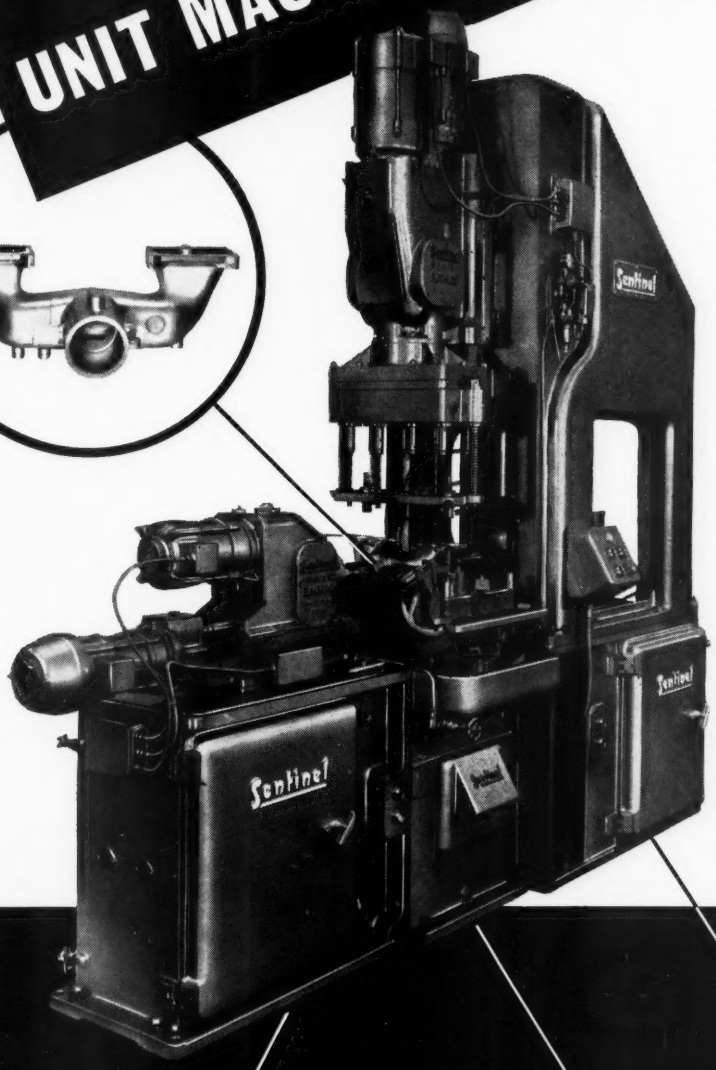
Sentinel UNIT MACHINES

FAST VERSATILE ECONOMICAL



SENTINEL UNIT MACHINES incorporating the Renault-France system electro-mechanical heads.
Built for—Drilling, Boring, Facing and Chamfering. 8 different types of Manifolds (*see inset*). Two manifolds are loaded, pneumatically located and clamped.
Press a button to start—and in less than 30 seconds the machining cycle is completed!

AN EXAMPLE OF FLEXIBILITY

This Unit Machine comprises a
3 ft. Dry Base, and an EMH 10 with Boring, Facing and Chamfering Tools.
3 way Centre Base.
4 ft. Dry Base, and an EMH 10 with Boring, Facing and Chamfering Tools.
Bridge Column, and an EMH 20 with a 12 multi-spindle head.

Vertical Column 7-8-9 ft.
3 ft. Wet Base
3 ft. Dry Base
5 ft. Dry Base
5 ft. Wet Base
Base for Vertical Column
4-Way Centre Base
Bridge Column on 4 ft. Dry Base

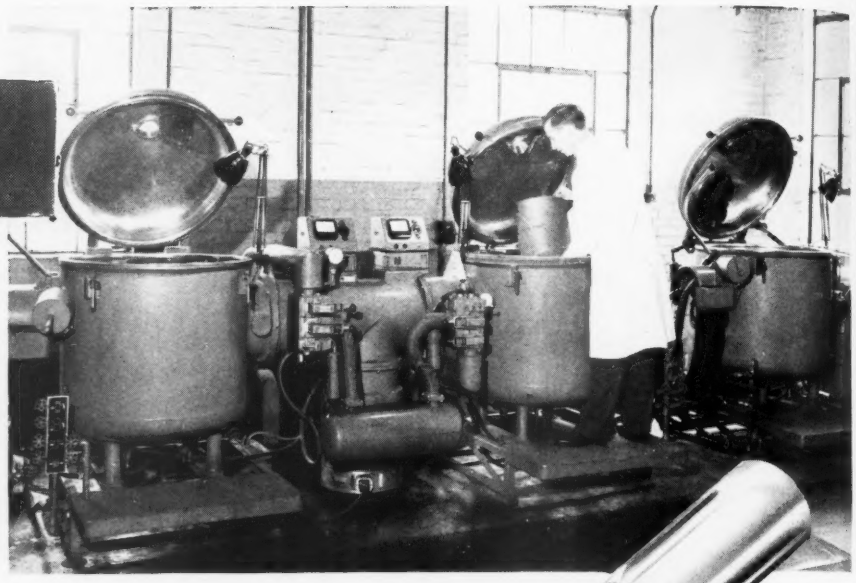
The standard bases (with enclosed switchgear) and rotary tables are available with machined mating faces for assembly into any combination of units.

SENTINEL (SHREWSBURY) LTD SHREWSBURY ENGLAND

Telephone: SHREWSBURY 2011 Telegrams: "SENTNOLL SHREWSBURY" London Office: 60 BUCKINGHAM PALACE ROAD LONDON S.W.1 Telephone: SLOANE 0098

P4108

FRUITS OF EXPERIENCE



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Ask for List No. 105

FRANK GUYLEE & SON LTD
ARCHER TOOL WORKS · MILLHOUSES · SHEFFIELD 8

Versatile —Powerful

— for heavy duty on a wide range of work.

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REVERSIBLE AUTOMATIC FEEDS AND QUICK POWER TRAVERSE IN THREE DIRECTIONS

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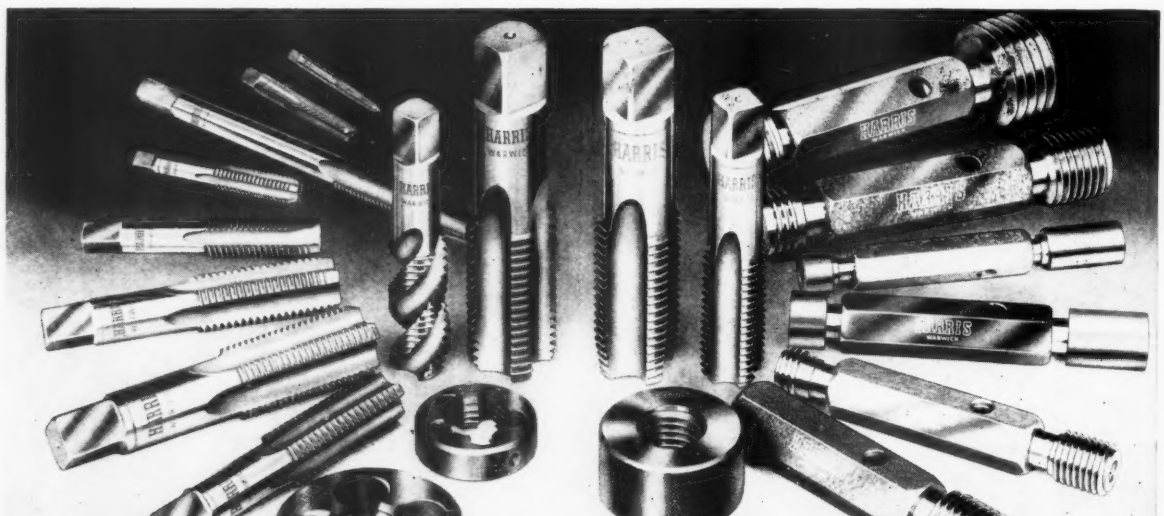

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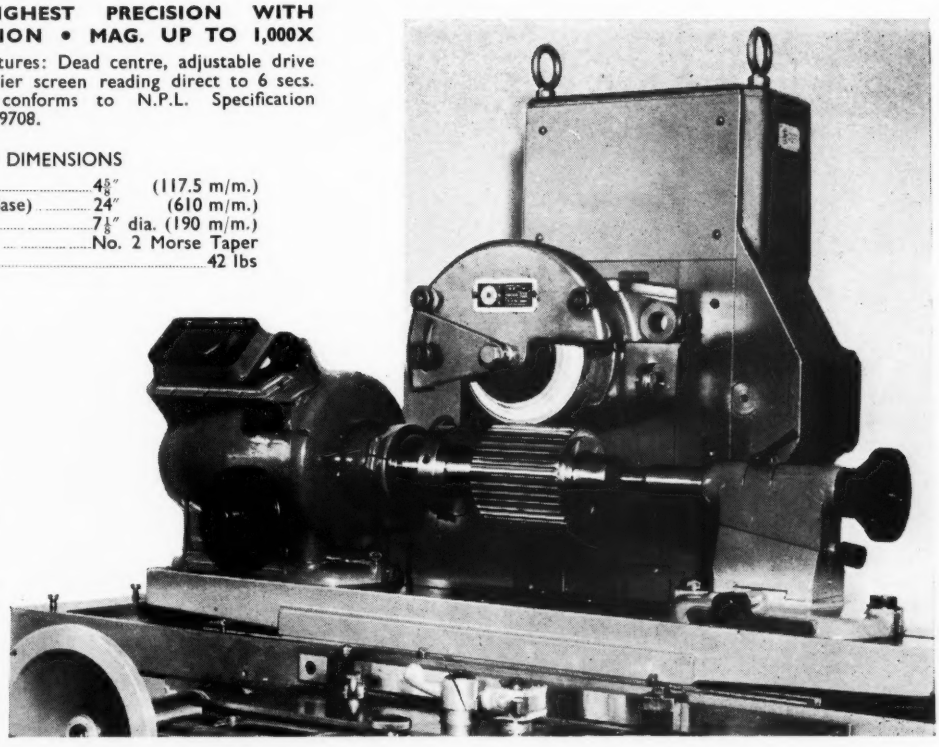
Centre Distance (on Base)	24″ (610 m/m.)
Size of Face Plates	$7\frac{1}{8}$″ dia. (190 m/m.)
Size of Centres	No. 2 Morse Taper
WEIGHT OF HEAD	42 lbs



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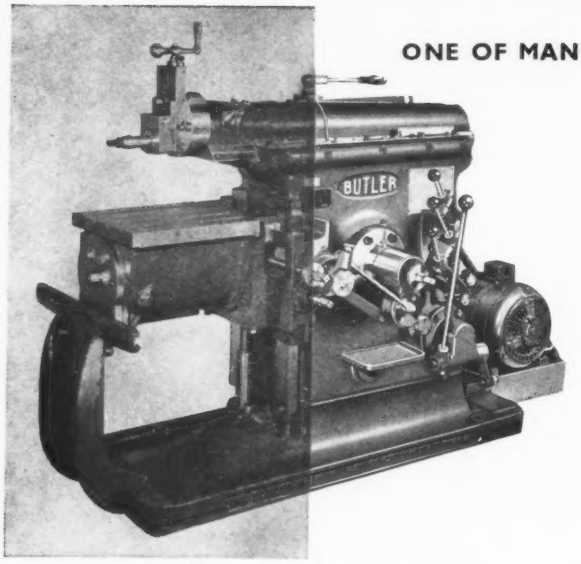

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TELEFLEX

DUAL DIRECTIONAL

CONVEYOR INSTALLATION

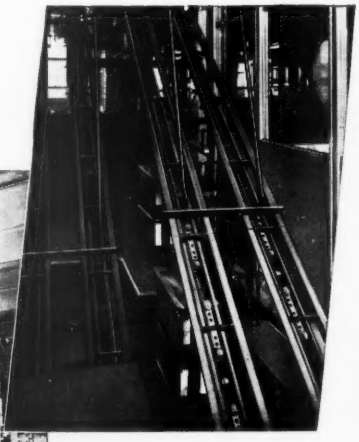
for

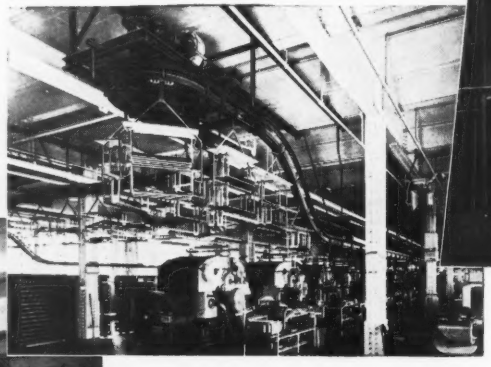
W.D.& H.O.Wills.

Glasgow Factory

Below and bottom left:

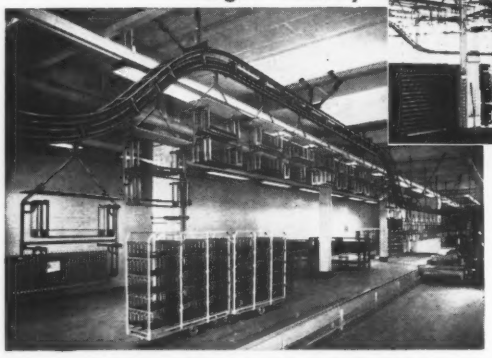
● *Two views of the Teleflex installation at the Glasgow factory. Note the simplicity of layout and the method of suspension from existing roof members.*





Above:

● *Showing elevation through different floor levels. Each circuit delivers full frames of cigarettes for packing and returns same for re-charging.*



Photographs by courtesy of Messrs. W.D. & H.O. Wills Ltd.

A complete mechanical handling scheme recently installed, for carrying cigarettes through their various stages of manufacture.
The system is elevated through different floor levels. The cradles are specially made to carry the stacking frames. This installation is an interesting example of the Teleflex Dual Directional system and its eminent suitability for being suspended from suitably located roof members.

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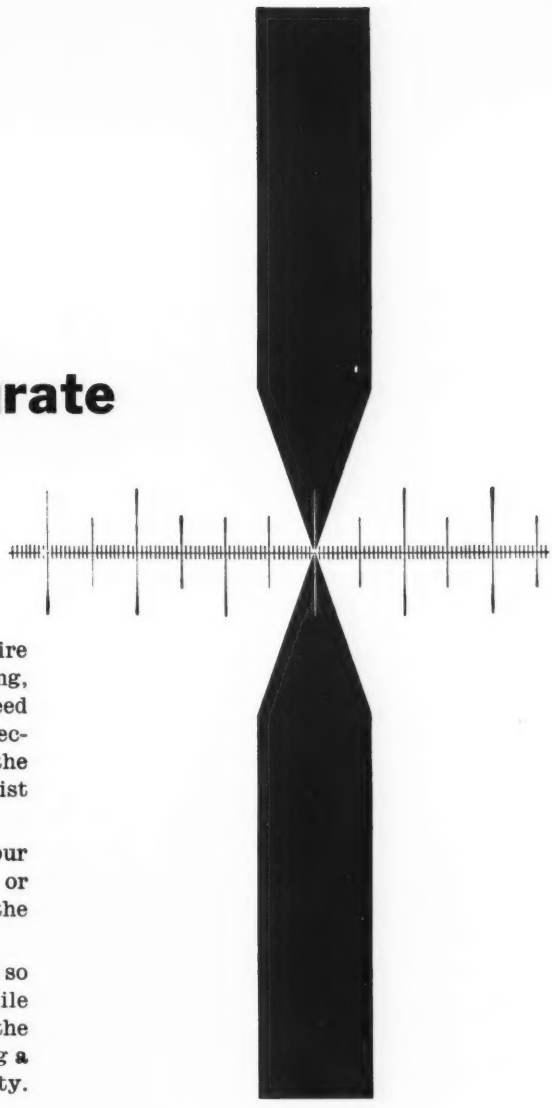

If at some stage in your process you require high operating speeds in sorting, batching, counting, computing, accurate and wide speed control, or non-destructive testing and inspection, electronic equipment can do it. If the appropriate equipment does not already exist it can be designed and made for your job.

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The only caper our Oldest Hand ever cuts, owing to his generous proportions, is the one that goes with boiled mutton. Our latest apprentice, however, is not unknown to lead the old man a dance at times.

"Get down off that barrel, Pavlova," our Oldest Hand orders sternly, "this is business, not ballet."

"Bally 'ot business, if you ask me," retorts our boy.

"Just pour a little Sternosol-Six* over yourself, lad," our old 'un advises, "it's known for cooling harder working things than you!"

Sternol *cutting oils*

* Please write for our cutting oil Schedule SS638.

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MOULD MAKERS

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★ **Full technical data will be sent on request.**

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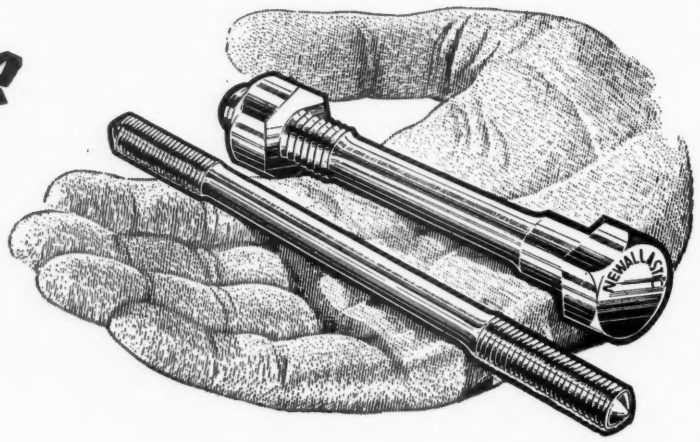
"Newallastic" bolts and studs have qualities which are absolutely unique. They have been tested by every known device, and have been proved to be stronger and more resistant to fatigue than bolts or studs made by the usual method.



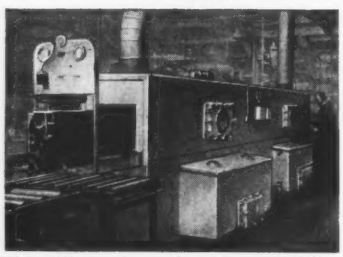
C. P. Newall & Co., Ltd.

POSSILPARK GLASGOW · N

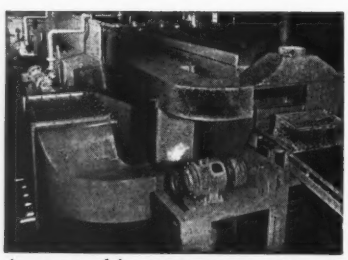
Bratby

HERE ARE THREE EXAMPLES

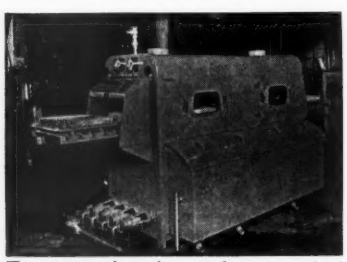
INDUSTRIAL CLEANING MACHINES *can be designed to meet your particular cleaning problems*



This illustration shows a machine cleaning crank cases in the production line. It is equally capable of cleaning small parts in baskets.



A power driven conveyor system is employed with this cleaning machine for ball bearings.



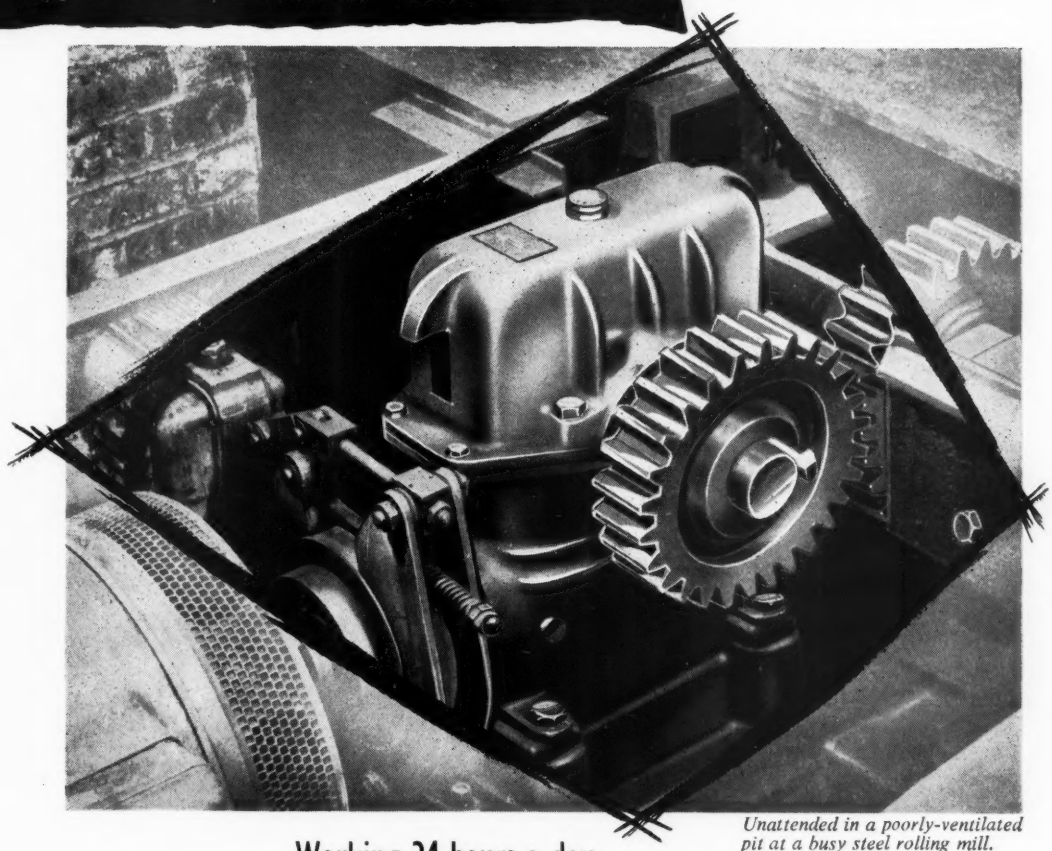
Trays carrying the work are pushed through on a roller conveyor by hand in this cleaning installation.

Whilst offering a very wide variety of standard cleaning equipment, it is BRATBY policy, wherever possible to design the machine to meet the particular cleaning problem. Careful study of each individual problem ensures maximum efficiency and economy of the plant in operation. The illustrations show but a few of the specific types of Cleaning Machines designed by BRATBY for individual needs.

Designed and Manufactured by:

BRATBY & HINCHLIFFE LTD · GORTON LANE · MANCHESTER 18 · Tel.: EAST 2435

no trouble at all...



Unattended in a poorly-ventilated pit at a busy steel rolling mill.

Working 24 hours a day to move 600 tons of hot steel a week and averaging 130,000 stops and starts a month, this Crofts Radiation Worm Reduction Gear conveyor drive has done a vital production job for over six and a half years.

And it goes on and on and on with no trouble at all, the only attention being maintenance of the correct oil level.

You can get first class gears like this from stock for powers up to 75 hp, ratios up to 60 to 1 and 1⅛" to 9" centres

PHONE BRADFORD 65251 EXTENSION 555 FOR IMMEDIATE ACTION

The standard range covers powers up to 450 hp—ask for Publication 521/A

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CF106

GEAR QUIZ ①

Q *Your No. 7 Hydrax Hobbing Machine looks good — what is its production rate for a 32 teeth helical gear, 12 D.P., 36° 58′ helix angle, ⅝″ face in E.N. 24 materials?*

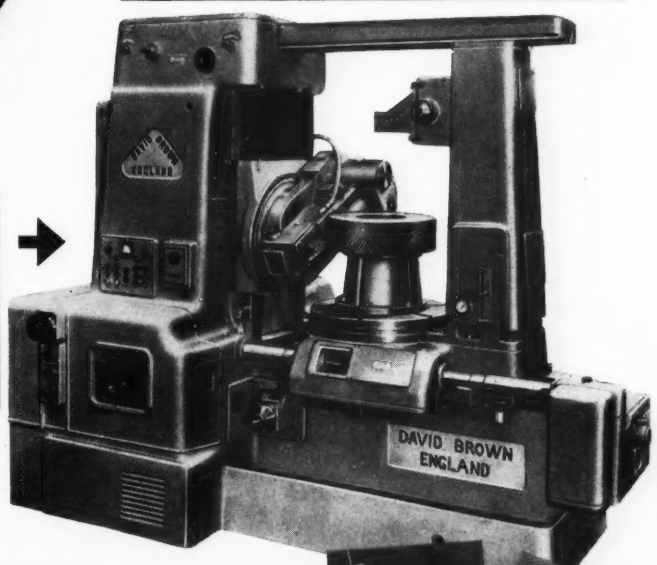
A **Two gears would be hobbed together using hand loading with fully automatic cycle. The floor to floor time per gear would be 55 secs. — 480 gears in an 8-hour shift. You benefit by the Hydrax technique and the finish would be suitable for shaving or grinding.**

WRITE ***NOW*** *FOR LEAFLET M. 104.4*

Q *This looks an extremely robust machine — what will it do?*

A **The PH30 Production Hobber, set for automatic cycle, will, to select a typical example, cut a 112 tooth helical gear, 5 D.P., 20° helix angle, 2″ face in E.N. 8 in 58 mins. floor to floor time. Three gears would be cut per setting and single roughing and finishing cuts only would be required.**

WRITE ***NOW*** *FOR LEAFLET M. 107.1*



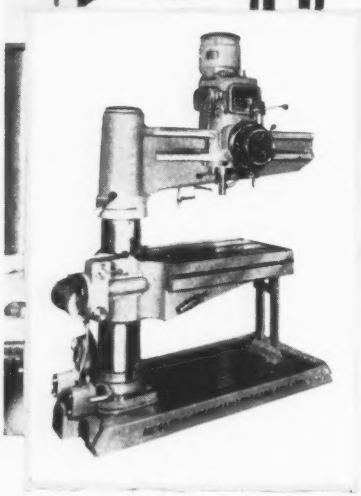
Q *We've heard about the tremendous production rate of this machine — what will it give us for our 32 teeth helical gears, 12 D.P., 36° 58′ helix angle, ⅝″ face in E.N. 24?*

A **Using the David Brown Oblique Traverse method, the S6H Shaving Machine will give a floor to floor time of only 32 secs. or 800 gears per 8-hour shift. The fully automatic cycle and changing would be used with hand loading.**

WRITE ***NOW*** *FOR LEAFLET M. 103.6*

Please address your replies to Gear Quiz

THE
DAVID BROWN
CORPORATION (SALES) LIMITED
MACHINE TOOL DIVISION
BRITANNIA WORKS SHERBORNE STREET
MANCHESTER 3



One of several SR2 Radial Machine Drilling Machines used by the Metal Box Company.

S.R.2

RADIAL DRILLING MACHINES

RICHMOND

Remarkably efficient—
YET SO LOW IN PRICE

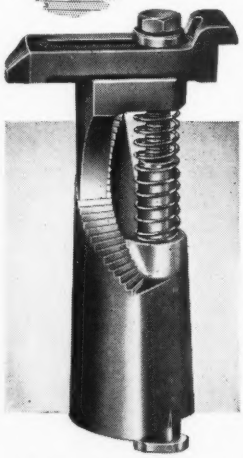
In two sizes — 36″ and 48″ radius — the S.R.2 drills up to 1¼″ mild steel 9 spindle speeds; nickel-chrome steel ground gears, heat treated to 100/110 tons per sq. in. Constant-flow pump supplies oil to gearing. Speeds (100-1,500 r.p.m.) selected through easily accessible levers.
An attractive optional extra available on this machine is a motorised table elevating unit for effortless control.

MIDGLEY & SUTCLIFFE LIMITED , HUNSLET : LEEDS
Tel.: 76032/3

ndh 1071

SLASH SET-UP TIMES with ROCKWELL HELICAL CLAMPS

BRITISH PATENT



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Fast easy mounting
Accurate and simple height adjustment
Small clamp projection over workpiece
2-position strap brings clamp close to work
Available in 22 sizes
Long trouble-free service

SIZE 1 for 7/16″, ½″, 11 and 12 mm. 'T' slots

No.	Heights
1/1	0 - 1⅜″
1/2	⅜ - 1¾″
1/3	1¼ - 3″
1/4	2⅜ - 5¼″
1/5	4¼ - 7⅜″
1/6	7 - 10″

SIZE 2 for ⅝″, ¾″, 14 and 16 mm. 'T' slots

No.	Heights
2/1	0 - 1⅜″
2/2	⅜ - 1¾″
2/3	1¼ - 3″
2/4	2⅜ - 5¼″
2/5	4¼ - 7⅜″
2/6	7 - 10″

SIZE 3 for 11/16″, ¾″, 17 and 18 mm. 'T' slots

No.	Heights
3/1	0 - 2¾″
3/2	1 - 2¾″
3/3	2 - 4⅜″
3/4	4 - 8⅜″
3/5	8 - 12½″

SIZE 4 for 1⅛″, 20 and 22 mm. 'T' slots

No.	Heights
4/1	0 - 2¾″
4/2	1 - 2¾″
4/3	2 - 4⅜″
4/4	4 - 8⅜″
4/5	8 - 12½″

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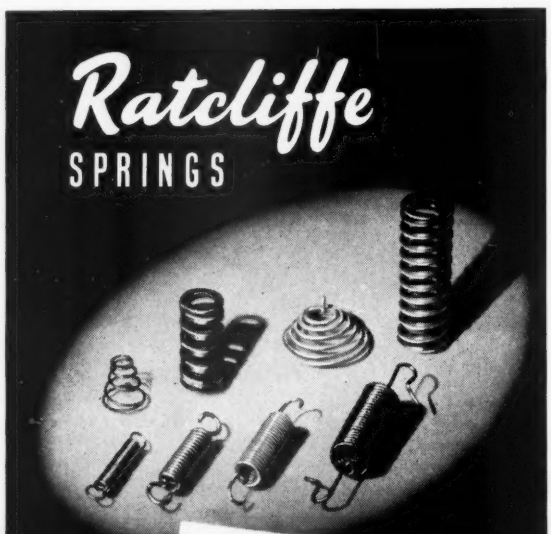

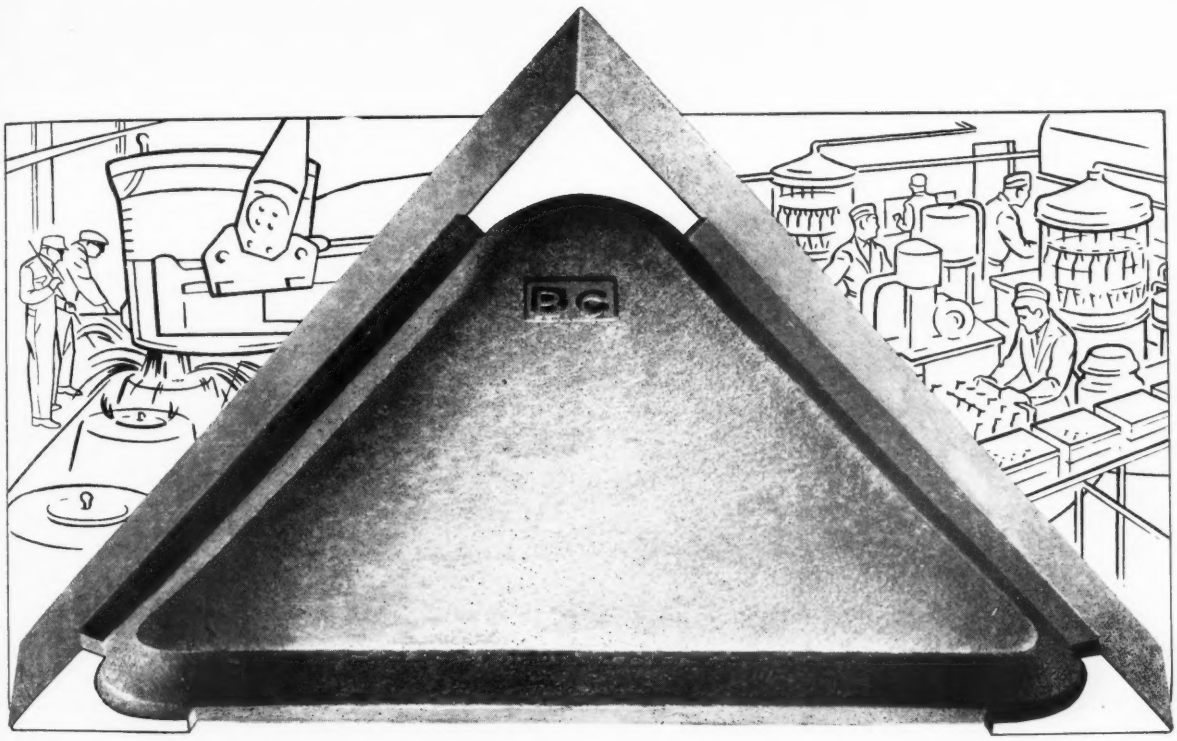

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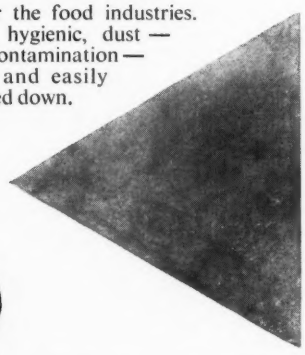

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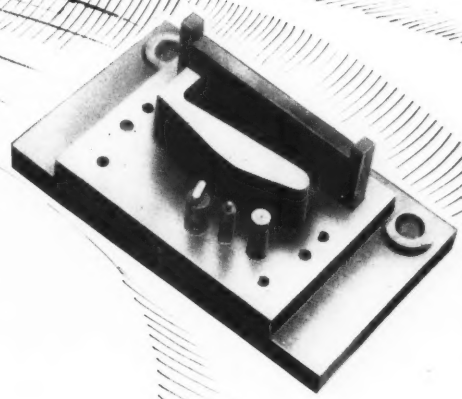

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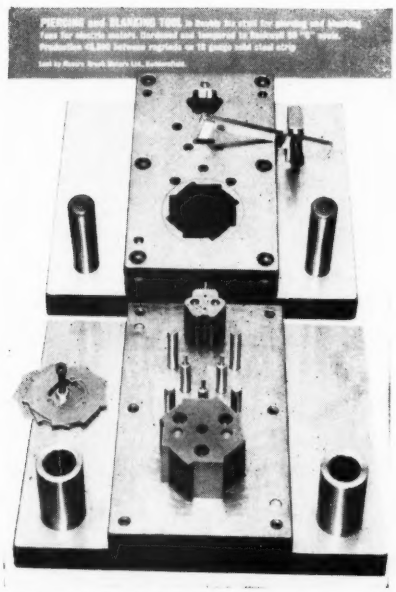

PIERCING and BLANKING TOOL in Double Six steel for piercing and blanking fans for electric motors. Hardened and tempered to Rockwell 60 "C" scale. Production 40,000 between regrinds on 18 gauge mild steel strip. Photograph by courtesy of Brook Motors Ltd., Huddersfield.

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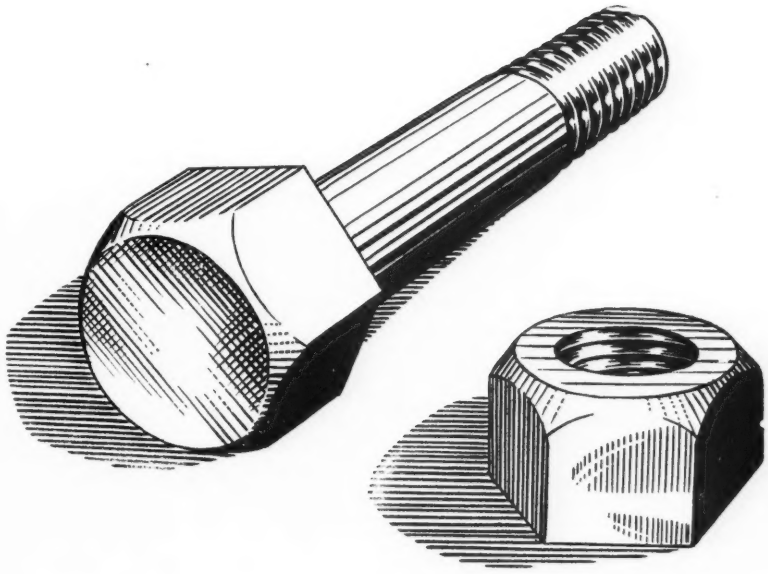

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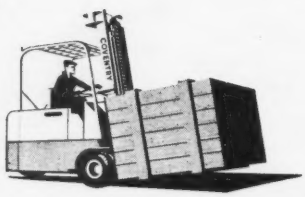

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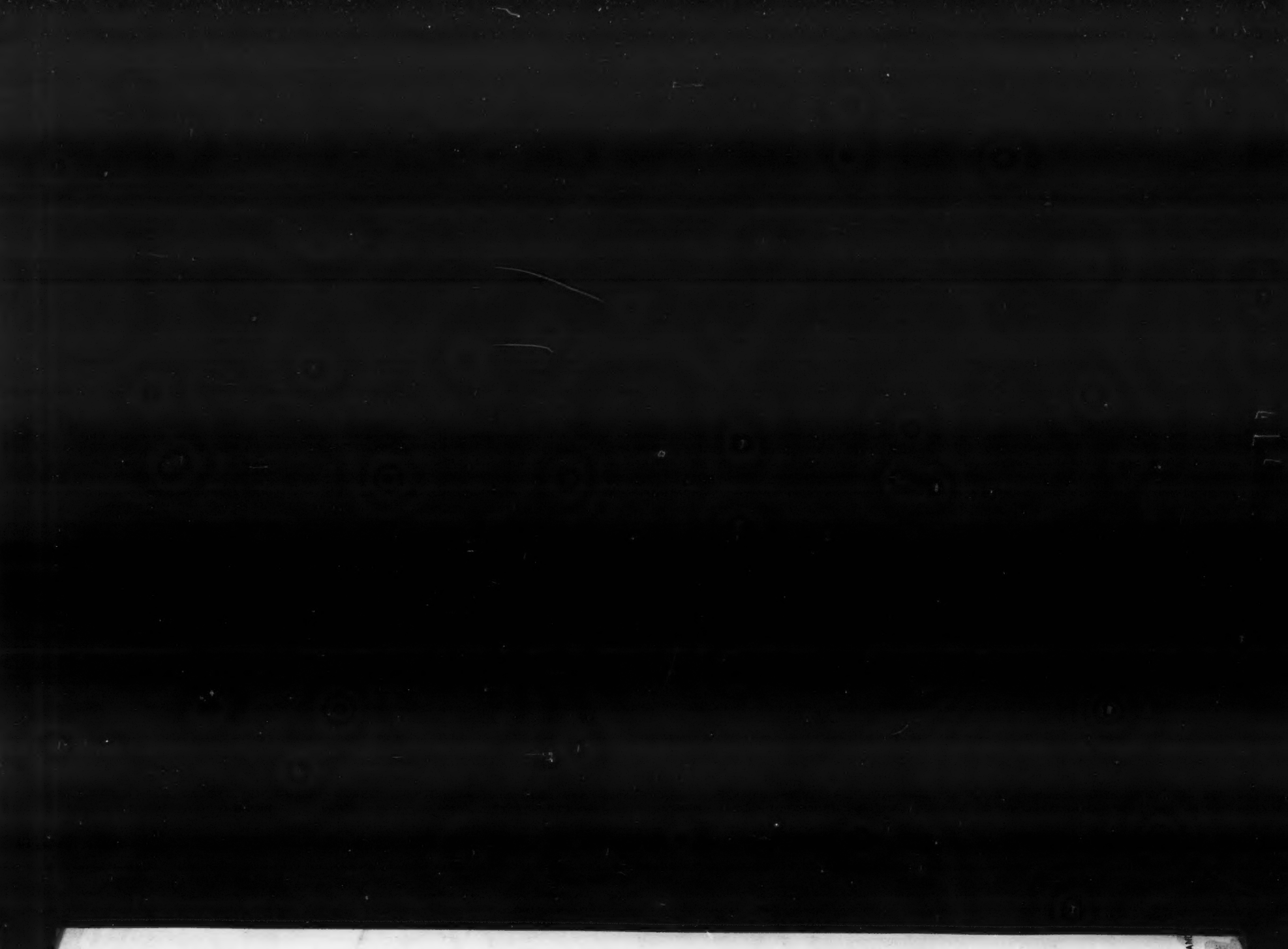
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